



The Shell Petroleum Development Company of Nigeria Limited
Operator of the NNPC/Shell/Agip/TEPNG Joint Venture

**ENVIRONMENTAL IMPACT ASSESSMENT (EIA) FINAL REPORT
FOR THE PROPOSED ENWHE FIELD DEVELOPMENT PROJECT
IN BAYELSA AND RIVERS STATE.**

BY

**SHELL PETROLEUM DEVELOPMENT COMPANY OF NIGERIA
LIMITED**

**SUBMITTED TO THE
FEDERAL MINISTRY OF ENVIRONMENT, ABUJA.**

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Abbreviations and Acronyms

%	Percentage
BH	Borehole
BOD	Biochemical Oxygen Demand
BYSEPA	Bayelsa State Environmental Protection Agency
C	Carbon
Ca	Calcium
CaCO ₃	Calcium Carbonate
cfu	Colony forming unit
Cl	Chloride
cm	Centimeter
CO	Carbon monoxide
COD	Chemical Oxygen Demand
CPF	Central Processing Facility
Cr	Chromium
Cu	Copper
dB	Decibel
DO	Dissolved Oxygen
DPR	Department of Petroleum Resources
EES	Environmental Evaluation Study
EGASPIN	Environmental Guidelines and Standards for the Petroleum Industries in Nigeria
EIA	Environmental Impact Assessment
EMP	Environmental management plan
FGD	Focus Group Discussion
FmoH	Federal Ministry of Health
GMoU	Global Memorandum of Understanding
GPS	Global positioning system
H	Hydrogen
H ₂ O	Water
H ₂ S	Hydrogen sulphide
HUB	Hydrocarbon Utilizing Bacteria
HUF	Hydrocarbon Utilizing Fungus
HIV/AIDS	Human Immuno-Deficiency Virus/ Acquired Immuno-Deficiency Disease Syndrome
HSE	Health Safety and Environment
HSE-MS	Health, safety and environment – management system
IOGP	Integrated Oil and Gas Project
ISO	International standard organisation
ITCZ	Inter-Tropical Convergence Zone
IUCN	International Union for the Conservation of Nature

K	Potassium
kg	Kilogramme
KII	Key Informant Interview
Km	Kilometer
LGA	Local Government Area
m	Metre
Mg	Magnesium
Mg	Milligramme
Mm	millimetre; million
Mn	Manganese
NAG	Non Associated Gas
NAOC	Nigeria Agip Oil Company
NOSDRA	National Oil Spill Detection and Response Agency
NO _x	Nitrogen oxides
NPC	National Population Commission
O ₂	Oxygen
P	Phosphorus
Pb	Lead
PO ₄	Phosphate
ppm	parts per million
QA/QC	Quality Assurance/ Quality Control
RH	Relative humidity
RoW	Right of Way
SCiN	Shell Companies in Nigeria
SO ₄ ⁻²	Sulphate ion
SPDC	Shell Petroleum Development Company
SPM	Suspended particulate Matter
STI	Sexually transmissible infections
TBA	Traditional Birth Attendant
TDS	Total Dissolved Solids
TDU	Thermal desorption unit
THB	Total heterotrophic bacteria
THC	Total hydrocarbon Content
TPH	Total Petroleum Hydrocarbon
VOC	Volatile Organic Compounds

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EXECUTIVE SUMMARY

E.S 1.0: Introduction

The Shell Petroleum Development Company of Nigeria Limited (SPDC), on behalf of its Joint Ventures partners (Nigerian National Petroleum Corporation, Total, and Nigeria Agip Oil Company) conducted a Environmental Impact Assessment studies for the Enwhe Field Development Project. The Enwhe field development project is an opportunity to sustain gas supply to NLNG and maximize utilization of Gbaran CPF by developing gas and condensate in the Enwhe field. The proposed activities for the development of the Enwhe field will have various interactions with the environment, hence the need to conduct an Environmental Impact Assessment (EIA) studies. In line with the provisions of Part VIII – Section A, 3.0 of the Environmental Guidelines and Standards for Petroleum Industries in Nigeria, 2002 (EGASPIN), an environmental screening of all concept options and a preliminary assessment of the selected option was conducted and approval issued. Post approval of the environmental screening and preliminary impact assessment report, the Terms of Reference/Scope of Work (ToR/SoW) was submitted to the Department of Petroleum Resources (DPR) and Federal Ministry of Environment (FMEnv) for consideration and an approval obtained. This EIA study has identified the key potential impacts of the project activities on Biophysical, Social and Health components within the project area and proffered mitigation measures for Environmental Management. The findings are hereby incorporated in this report.

E.S 2.0: Project Location

The Enwhe field is located in the south-western corner of license block OML 22 and extends into license block OML 23 and is located about 36km to the East of Gbaran CPF. The field is part of the Gbaran Ubie Node which is a multi-field oil and gas asset. The Enwhe field is bounded by creek and creeklets of Orashi and Nun River. Major communities in the Enwhe field lies in Yenagoa Local Government Area of Bayelsa State, Ahoada West and Abua/Odual Local Government Areas of Rivers State.

E.S 3.0: Objectives of the Environmental Impact Assessment

The objectives of the Environmental Impact Assessment studies of Enwhe Field Development Project include but not limited to the following:

- establish the baseline conditions of the project area with respect to the biophysical, social and health environment.
- identify and evaluate the potential impacts of the project activities on the biophysical, social and health environments of the area.
- identify and assess the potential socio-economic effects of the project on the communities' livelihood patterns, including impacts on cultural properties, social infrastructures, natural resources and values.

- identify and evaluate health impacts that may be associated with different activities of the project.
- develop cost-effective mitigation measures and appropriate Environmental Management Plan (EMP) for sustainable development.

E.S 4.0: Legal and Administrative Framework

The statutory (legal and administrative) frameworks within which the Environmental Impact Assessment study was executed are provided by the following regulations, guidelines and standards:

- DPR Petroleum (Drilling and Production) Regulations (1969)
- The Federal Ministry of Environment (FMEnv) regulations, guidelines and standards on oil and gas activities in Nigeria.
- All International Conventions on Environmental Protection to which Nigeria is a signatory eg; African Convention on the Conservation of nature and Natural Resources, 1968; International Convention on Civil Liability for Oil Pollution Damage, 1969 AND Convention Concerning the Protection of the World Cultural and National Heritage (World Heritage Convention), 1972.
- The regulations, guidelines and standards of the Bayelsa State Ministry of Environment (Bayelsa State Environmental and Development Planning Authority Law 1998; Bayelsa State Pollution Compensation Tax Law 1998 and Bayelsa State Land Use (Environmental Degradation/Protection) Charge Law 2005).
- The regulations, guidelines and standards of the Rivers State Ministry of Environment (Rivers State Environmental Protection Agency Law, No. 2 of 1994; Rivers State Private Health and Allied Establishments Authority Law, 2001, Rivers State Public Health Law, 1999 and Rivers State Noise Pollution Control Law of 1984).

E.S 5.0: Need for the project

The Enwhe field development is expected to develop 767 Bscf of gas and 7 MMstb of condensate of the total field recoverable volume of 834 Bscf of gas and 15 MMstb of (oil and condensate), within the expected production life of the Gbaran CPF. The value drivers identified for the Enwhe FDP include but not limited to the following:

- Meet NLNG Gas Supply obligation - sustaining the planned DCQ as long as possible.
- To improve the recovery factor in the node towards the Top Quartile bracket.
- Reduced CAPEX - achieving low unit development cost to align with Partners aspiration and facilitate funding.
- Reduced OPEX - achieving low unit operating cost by utilizing remote operations capability to cut down on operator intervention and exposure considering remoteness of Enwhe field from Gbaran CPF

E.S 6.0: Value of the project

The revenue that will accrue from the sales of gas to be produced from these wells will substantially increase the foreign exchange earnings of the Federal Government and help to improve the social and health standards of the inhabitants of the area covered by the project. The 100% JV P50 cost estimate for Enwhe Tranche-1 development approximately 450 mln USD (Wells =200 mln and Facilities = 250mln).

E.S 7.0: Envisaged Sustainability

The proposed Enwhe FDP consists of gas development (Tranche-1), and oil & gas development (Tranche-2). The Enwhe field development project is an opportunity to sustain gas supply to NLNG and maximize utilization of Gbaran CPF by developing gas and condensate in the Enwhe field. The Enwhe FDP is envisaged to be environmentally, technically, economically and socially sustainable.

Economic Sustainability

A long term gas sale agreement (GSA) is in place that commits SPDC to supply an average Daily Contractual Quantity of 1,941 MMscf/d to the six NLNG train. It is an opportunity to sustain gas supply to NLNG and maximize utilization of Gbaran CPF by maturing 0.83Tcf of recoverable gas and 15MMbbls of oil and condensate. The Enwhe field has proven reserves of gas that can economically and commercially support the project thereby contributing to the revenue accruing to Nigeria and SPDC.

Technical Sustainability

This project is technically sustainable because of SPDC's proven oil and gas technology and strict adherence to internationally and nationally acceptable engineering design and construction standards. Innovative technologies that are economically viable and having minimal environmental, social and health impacts shall be utilised in the execution of the proposed project. New gas wells will be drilled and flowlines constructed to transport the gas to a gathering manifold, from which the gas will be transported via a bulk line to the Central Processing Facility (CPF). The CPF has gas dehydration facilities for high pressure AG and NAG treatment prior to export to NLNG.

Environmental Sustainability

National and international regulatory and engineering design standards, innovative technologies that have minimal environmental, social and health impacts shall be utilized in the execution of the proposed project. The incorporation of the findings and recommendations of this report at the various stages of the project development and strict adherence to the Environmental Management Plan (EMP) will ensure environmental sustainability.

Social Sustainability

The integration of appropriate social impact assessment and community interface management mechanisms in the Project are critical success factors to the realization of overall business

objectives and SPDC corporate reputation in the area. A stakeholder engagement plan has been developed and all stakeholders, especially communities, partners, regulators and other government agencies will be engaged in a proactive and respectful manner to engender participation and secure enabling environment for the Project. The deployment of GMoU and allied processes for interface management and delivery of basic community development intervention projects and programs is critical to the success of this project. Its scope will ensure that we do not create legacy issues, but enhance community participation in the business through active collaboration with SPDC Community Content Team. Skills will also be developed and business supported to enable community participation in the project execution phase and beyond. Approximately, 2.5% of project cost (CAPEX) shall be provided for the implementation of Social Performance intervention programs and projects in the impacted communities. The fund assigned for community development through the GMoU shall be paid into a joint account maintained with the communities in tranches and spread over the duration of the agreement, which will also align with the duration of that project.

E.S 8.0: Project Options

The Project Options include:

- No Option: This option entails not implementing the project.
- Delayed Project Option
- Develop the Enwhe field

The development alternatives/concepts for the Enwhe FDP were as follows: Low Capex, Smart Field and Optimized development of the field. The differences between the concepts are the Well counts, gas rate, sand control, degree of smartness and pipeline construction.

Low capex Option: This is focused on a low development cost concept, fewer wells etc. In severely funding constrained environment, this concept is the most attractive

Smart Field: This is focused on minimizing impact on community during production by minimal operational interventions. This concept is best on SD consideration.

Optimized Development: This involves development with optimized philosophy (i.e. right amount of wells, complexity, etc). The selected concept is Optimized Development which involves gas development with optimized philosophy (i.e. right number of wells), use of one manifold location at Enwhe West, acceptable level of Smartness (ALoS), use of fully rated lines and Multiphase flowmeters for metering and allocation.

Drilling Location alternatives

Drill a total of 6 NAG wells with 11 reservoir targets as part of tranche-1 development.

Advantages

- Prompt development of the reservoirs identified as ready-to-go-gas which includes NAG reservoirs and oil rim reservoirs with less than 20ft oil column or fluid uncertainty.
- High gas volume in the reservoirs.
- Drilling from new location is less complicated.

Risk of delay and not delivering on promises to stakeholders is low.

Disadvantages

- Higher overall costs
- Additional land take

Remarks: Recommended

Drilling from existing Enwhe Wells in the Orashi forest reserve

Advantages

No new landtake

Disadvantages

- The location of the current wells is in and around government protected forestry reserves (Orashi Forest reserve).
- Due to the age of the wells (49 years), they did not pass the minimum requirement for gas well completions

Remarks: Not Recommended

Pipeline Options

Pipeline Route 1: The selected route takes off from the Remote Enwhe Manifold in a North-Easterly direction, avoiding the forestry reserve. The route then runs in a North Westerly direction to Gbaran CPF. The route crosses a river at between and Road Crossings. The communities in proximity to the proposed route include: Okarki, Odua, Egbema, Ikodi (**Recommended**).

Pipeline Route 2: Runs from Enwhe flowstation. It runs Westward along the 16'' Nun River to Kolocreek trunkline RoW, then across the Upper Orashi Forest reserve and terminates at the Kolocreek flowstation. (**Not Recommended**).

Pipeline Route 3: Runs Enwhe flowstation towards the South Eastern flange of the area of interest. It runs parallel to the pipeline to Oloibiri flowstation then runs southwards along the EGGS pipeline to Soku GasPlant. (**Not Recommended**).

Pipeline Route 4: Runs from Enwhe Flowstation to Kolocreek flowstation running parallel to Option 1 Pipeline. It runs southwards then west parallel to Option 2 before terminating at the Kolocreek flowstation. (**Not Recommended**).

ES 9.0: Project objectives

The objective of this development is to develop some 0.83 TCF of gas and 15 MMstb Condensate and Oil in Enwhe field aimed at sustaining NLNG gas supply obligation at 2 Bscf/d and address potential demand gap beyond off plateau date of 2021.

Proposed Project scope/Overview

The selected concept for Enwhe Opportunity is the Optimized Development termed “Just about Right Wells and Facilities”. The scope involves mainly drilling, completion of wells and hook-up to the Gbaran CPF.

NAG development Scope:

- Drill and complete 6 wells from 2 wellhead cluster locations.
- Drill one exploration well
- Drill 2 appraisal wells
- Construct 6 x 6” duplex steel flowlines of 1.5km lengths (total length 7 km).
- Install two remote manifold with multi-phase metering and chemical injection skid (Enwhe East and Enwhe West remote manifolds).

Pipeline scope:

The pipelines’ scope for the Enwhe field development scope will include, but will not be limited to:

- Design and installation of the following flowlines:
 - Three 0.3 km flowlines from Enwhe East locations to Enwhe East NAG Manifold
 - Three 0.3 km flowlines from Enwhe West location to Enwhe West NAG Manifold
- Design and installation of hook-up arms for the NAG wells
- Design and installation of the Enwhe NAG remote Manifolds
- Design and installation of a new 36.41km long, 12” NAG bulkline from the Enwhe NAG Manifold to the Gbaran CPF
- Design and installation of pigging facilities including the pig traps and associated pipework and valves. The Bulkline extends from pig launcher to pig receiver.

Pipeline Dimensions

- 1 no. x 12” 36km Enwhe – Gbaran CPF Bulkline
- 1 no. x 12” 5.5km Enwhe East – Enwhe West Bulkline
- 3 no. x 6” 0.3km Enwhe East flowlines
- 3 no. x 6” 0.3km Enwhe West flowlines

ES 10.0: Project Activities scope for Enwhe Field Development Project

Pre-mobilization

Pre-mobilization activities shall include community and other stakeholder engagements and land acquisition. This phase will also include designs and off-site fabrications of modules, pipes etc.

Mobilization Phase

This phase will involve:

- Moving construction equipment (dredger, bulldozers, excavators, graders, rollers, pay loaders, asphalt pavers, tippers, trailers, swamp bogey, generators, self loaders, cranes, crew bus, 4WD truck, welding sets, Flushing pumps, Hydro testing unit, Generators, Compressors, Bending Machine, Grit blasting unit, Oxy acetylene torch, Line up clamps, Cold cutter, X-ray units, Thrust boring machine etc) from Contractor's base to site.
- Movement of temporary offices and accommodation to site.
- Set up site office and yard (telecommunication masts, temporary sewage system, messing facilities).
- Movement of personnel from Contractor's base/ SPDC office to site by road.
- Movement of rig to site (this is captured as part of mobilization for the purpose of impact assessment although this comes after well location preparation).

Construction Phase

Well Locations Preparations

Well location preparations shall typically involve vegetation clearing, sand filling, pilling, concrete and asphalt works.

Drilling Workslope and Activities

Logging

This is the electrical/nuclear investigation of the drilled well to ascertain the lithology and fluid content. The interpretation of the log data gives an indication of the presence and the quantity of hydrocarbon (in this case gas) in the formation.

Completion

This is the process of hooking up a well for production. The process involves logging, well-bore clean-up, perforation, production testing, sand consolidation and installation of the Christmas tree. The completion of the drilling will be the hooking up to the field manifold.

Pipeline Project Activities

Survey and Staking of Pipeline Routes

Survey shall be carried out to re-establish and clearly mark out boundaries of the permanent ROW and temporary working strip required for construction activities.

Probing for existing facilities

Along existing RoW and at brownfield locations, existing facilities shall be identified and located using drawings and pipe detectors. Manual excavations at appropriate intervals shall confirm exact positions. Inspection of each exposed location shall be carried out and a permanent mark placed on all exposed lines and facilities to indicate which are to be removed and which are to be left in place.

Clearing and grading

The working width shall be cleared of trees and hedges. Ditches shall be flumed by installing pipes and ramped over with subsoil to give a continuous running track through the fields. Topsoil shall then be stripped across the working area and stored at one side. An area of the working width adjacent to the stored topsoil shall be designated as a running track for vehicular movements.

Trenching

A trench, nominally 0.3 – 0.6 m wider than the pipe diameter and deep enough to provide minimum cover, will be excavated to for the pipelines burial. Where the pipeline has to cross existing facility the trench depth will be increased to allow a gap to exist between the two facilities.

Stringing and bending

Stringing and bending involves the handling and positioning of pipes or joints along the ROW on one side of the trench in preparation to welding into a continuous pipeline. Line pipes shall be transported to site from the pipe dumps or lay down areas and laid out on wooden skids along a line parallel to the proposed trench.

Welding

Before welding, each item shall be visually inspected to ensure that the integrity and general condition of the pipes and fittings have not been compromised during transportation and storage, that they are clean internally and that the ends are correctly prepared for welding. Repairs on any damaged item would be done. Once pipes have been certified fit for use the pipes shall be lined up for welding. Pipes shall be checked, fitted and cleaned to ensure their quality prior to welding. Pipes and fitting shall be lined up for welding with all end caps and similar protections removed immediately before lining up each pipe or fitting. Welding of the joints shall be in accordance with sections 21, 25 and 34 of Shells standard construction specifications. A pipe tally shall be kept showing records of pipe length and wall thickness and number of welds made.

Inspection testing and NDT of welds

Quality assurance and control of the weld shall be achieved by visual inspection and radiographic inspection. 100% radiography of all weld joints shall be employed. All radiography films will be processed and interpreted on site to facilitate quick repairs of defective welds. Records of test results shall be prepared and submitted on a regular basis. Defects shall be repaired or cut out.

Field coating

The weld joint sections and any other sections of the pipeline which are bare or which the coating has been damaged shall be coated to form a continuous protective coating. Heat shrinkable sleeves or repair patches shall be used for repairs of defective field joint coatings taking into account the extent of the portion to be repaired.

Lowering

The welded pipe shall be lowered gently into the ditch without subjecting the line to any stress. The pipes will conform to the ditch and substantially supported by the ditch bottom. The bed underneath the pipe shall be prepared by installation of soft material (medium sand bed) to obtain a soft surround for the installed pipe.

Tie-in

After the pipeline sections are lowered into the trench, the sections will be welded together and field joint coated after has been ensure that the integrity and general condition of the sections have not been compromised during lowering. Quality assurance and control of the tie-in weld shall be achieved by visual inspection and radiographic inspection.

Backfilling

Backfilling operation shall follow as closely as possible the lowering and tie-in in operation so that the pipeline and its protective coating will not be damaged. settlement.

Cathodic Protection

Permanent cathodic protection (CP) facilities shall be installed to protect all Enwhe pipelines. Protection source shall be from deep well ground bed installed at the CPF and remote manifold locations to be determined during design.

Hydrotesting, Pre-Commissioning and Commissioning

Cleaning, Testing, De-watering and Drying

After all pipeline and manifold sections have been constructed, inspected and tied in, hydro-testing, pre-commissioning and commissioning will be carried out. Hydro-testing and pre-commissioning involves cleaning, gauging, flooding, hydrostatic pressure testing, de-watering and conditioning of the pipeline systems. It may also involve function checking of valves and other systems.

Commissioning and Handover

A pre-commissioning audit of the newly constructed pipelines to verify their conformity with the construction drawings and operability shall be carried out. The contractor shall participate in the pre-commissioning audit, and shall effect any remedial works identified.

Decommissioning, Abandonment and Restoration

The decommissioning of the project facilities shall involve these main activities:

- Determining the regulatory requirements
- Evolving a community involvement strategy
- Establishing future land use objectives
- Determining objectives of the mothballing plan
- Determining remediation requirements
- Determining reclamation objectives
- Developing a HSE plan

Techniques for river crossing

Along the pipeline corridor, there is one (1) major river (Orashi River), one (1) medium river of approximately 100m width, and several minor rivers (width up to 50m). Open cut method shall be considered at minor river crossing. For the major and medium river crossings, HDD, floatation method or push and pull method could be employed, however CONTRACTOR shall assess the areas at the time of construction and propose suitable construction methods for COMPANY's approval. Uncased Thrust boring shall be considered at Major road crossing, and open cut method at minor road crossing.

River and Creek Crossings

At creek/river crossing, the following RoW extent shall apply:

- Medium size creeks/water crossings of between 50m and 200m, the ROW shall be 30m.
- Major water crossings wider than 200m, the RoW shall be 60m.
- On each bank of the crossing, the enlarge RoW width shall extend 30m inland from the bank.

E.S 11.0: Waste and/ or By-products Generated

Drilling Waste

The drilling waste management principles in this project will focus on waste minimisation and recycling. The wastes that will be generated during the drilling operations are: Drill cuttings / excess , Spent drilling mud and completion fluids, Cementing waste and Drilling effluents (waste water).

Waste from Pipeline laying activities

Scrap metals, Food wates, Wood, Glass wastes and Plastics.

ES 12.0: Decommissioning, Abandonment and Restoration

The decommissioning of the project facilities shall involve these main activities:

- Determining the regulatory requirements
- Evolving a community involvement strategy
- Establishing future land use objectives
- Determining objectives of the mothballing plan
- Determining remediation requirements
- Determining reclamation objectives
- Developing a HSE plan

ES 13.0 Project Schedule

Mobilization to site, and other major pipeline activities are scheduled for Q3 2017. Drilling of Enwhe Wells and Bukline construction is expected to commence in 2019.

ES 14.0: Description of Existing Environment

The purpose of the baseline data acquisition is to establish, before the execution of the project, the status of the various environmental components that are likely to be affected by the proposed project. A multi-disciplinary approach was adopted for data acquisition and ecological characterization which included climate, air quality and noise, soil, land use/land cover, vegetation, wildlife and biodiversity, aquatic, geology, social and community health status. Data were also generated through literature review of existing environmental studies report in the area, consultations with the stakeholders, detailed field work/study, laboratory and statistical data analysis. Furthermore, a proper Participatory Rural Appraisal/Assessment technique and sampling could not be conducted due to heightened Security challenges especially around Abua/Odual Local Government Area in Rivers State. Also, inaccessibility to some sampling stations especially in the Dry season lead to the short fall in the number of samples approved in the Terms of Reference.

ES 15.0: Literature Review

Some information used for the description of the environment in this report was obtained from the following documents:

- Environmental Management Plan for Gbaran Infill Project, 2016.
- Scientific publications.

ES 16.0: Description of Sampling location

The Enwhe FDP Environmental Impact Assessment Studies involved a two season field data gathering (30th to 12th September, 2016 (Wet season) and 14th to 28th November, 2016 (Dry season)) and covered a spatial boundary of 1km on either side of the proposed Pipeline RoW. Similarly, the study also covered a spatial boundary of 2km radius of the proposed well locations in the Enwhe field. The stratified sampling design protocol was adapted for the study. The summary of sampling points for various environmental spheres are as follows:

- Soil quality; WS: 63 + 2 control; DS: 45+2control
- Surface water/Sediment quality: WS: 17 +2 control; DS: 13+2control
- Groundwater: WS: 11+2 control; DS: 11+2 control
- Vegetation/ Wildlife: WS: 63 + 2 control; DS: 45 + 2control
- Air quality/Noise: WS/DS; 21+2control

ES 17.0: Quality Assurance/Quality Control

The following QA/QC was observed in sample collection and *in situ* analysis carried out in the field. Samples were collected in bottles that have been thoroughly washed with detergent (nutrient free) and rinsed thoroughly. Prior to sample collection, each container was rinsed with the water to be sampled before finally collecting the representative sample for laboratory analysis. All samples were analysed at Earthquest International Limited, Warri, Delta State.

- All sampling equipment were properly protected and maintained in accordance with manufacturers' manuals.
- Sampling bottles were adequately labeled with masking tapes and indelible markers to avoid mistaken identity.
- Only analytical reagents (Analar grade) and chemicals were used.
- Automated equipments were calibrated prior to field sampling
- The same stock solutions and standards of H₂SO₄, HNO₃, Na₂S₂SO₃ Winkler's (A and B), and Starch Indicator were used for all the batches of samples to ensure comparability and reliability of results.

ES 18.0: Results

Climate and meteorology

All climatological and meteorological parameters including Temperature (Mean: 29.65-32.45°C), relative humidity (Mean: 60.68-71.90%), wind speed (0.55-1.5 m/s), wind direction and air pressure (Mean:1007-1011.7) are normal for the study area.

Air Quality and Noise

All measured Air quality parameters were within regulatory limits. Heavy metals, Nitrogen dioxide, Sulphur dioxide, hydrogen sulphide, ammonia, volatile organic compounds, and ozone were undetected. Carbon monoxide (Mean: 0.01 ppm) and suspended particulate matter (0.83-2.03 µg/m³) were below the respective permissible limits (10 ppm & 250 µg/m³). Noise levels (Mean: 50.34-55.3dBA) were within regulatory limits (90 bB(A)).

Surface Water Quality

Physicochemistry

Most of the surface water physicochemical parameters such as pH, redox potential, conductivity, dissolved oxygen, BOD, COD, nitrate, phosphate, alkalinity, sulphate, cations, heavy metals and oil & grease were within normal limits for unpolluted surface waters. Turbidity and Total suspended solids were high at all locations including the control particularly during the wet season

(eg. Wet season control Mean: 15045 NTU). High turbidity in surface waters are common in the Niger Delta and is related erosion and surface run-off into the rivers during rains. All measured physicochemical parameters showed a tendency to increase during the rainy season which is attributed to rain-related surface run-off into the rivers.

Microbiology

Levels of Total Heterotrophic Bacteria (THB), Hydrocarbon Utilizing Bacteria (HUB), Total Heterotrophic Fungi (THF) and Hydrocarbon Utilizing Fungi (HUF) were all within normal levels for the unpolluted surface waters. Coliform bacteria were detected in the surface waters (Mean:2-10 MPN/100 ml) making the waters hazardous to health and unsafe for human consumption

Sediment Quality

Texture

The sediment was dominated by sand in the dry season but during the rainy season silt and clay dominated in some location mainly due to erosion and surface run-off input of materials from the catchment.

Physicochemistry

Sediment physicochemical factors including pH, redox potential, electrical conductivity, total organic carbon, oil and grease (Mean: 3.9-7.4 ppm), nutrients, exchangeable cations and heavy metals were all within normal levels for unpolluted sediments. Variations were mainly seasonal due to erosion and surface run-off from the catchment into the surface waters.

Microbiology

Levels of Total Heterotrophic Bacteria (THB), Hydrocarbon Utilizing Bacteria (HUB), Total Heterotrophic Fungi (THF) and Hydrocarbon Utilizing Fungi (HUF) were all within normal levels for the unpolluted sediments. The ratios of HUB to THB were well below 10%, signifying absence of oil pollution in the environment.

Soil

Soil Texture: Soil texture ranged from clay loam to sandy loam with higher proportion of clay in and silt during the wet season compared to higher proportion sand during the dry season. Particle size distribution varied widely between surface and subsurface levels and between wet and dry seasons compared to control locations. The seasonal flooding which characterizes the study area is the main cause of the wide seasonal and spatial variations observed in the textural characteristics of the soils.

Soil Porosity and permeability: Soils porosities (approximately 50%) are normal for the area, the higher dry season values being linked to the reduced moisture content of the soils. Soils

permeability was generally <2 cm/hr and are considered low compared to soil critical value of 5 cm/hr. This is good for groundwater protection from infiltration of pollutants.

Bulk Density: The bulk density of soils in the study area were generally low (<0.5 g/cm³) but were within the acceptable range of < 1 g/m³. The low bulk density is related to the low organic matter content of the soils.

Conductivity and pH: Soil conductivity (<100 μ S/cm) was well within recommended limit of 150 μ S/cm for good agricultural soils. The soil pH was generally acidic at all locations with lower values ($<<5$) in some locations. The levels were low when compared with recommended levels of 5.5-7.5 for good agricultural soils. The acidic nature of the soils may be associated with the seasonal flooding characteristic of the study area.

Total Organic Carbon (TOC): TOC levels were low ($<1\%$) when compared with recommended levels of $> 2\%$ for good agricultural soils. At all locations lower values were obtained during the wet season. Surface levels were also higher than subsurface levels.

Oil and Grease

Oil and Grease and Total Hydrocarbons showed relatively higher values during the wet season and at surface levels compared to subsurface levels but concentrations were generally very low at all study locations indicating absence of oil pollution in the area. Levels of THC (generally <1.5 mg/kg) are within background levels of mineral oils in soils (100 mg/kg-Beyer, 1990)).

Nutrients: Levels of nitrate were below 2 mg/kg at most locations which is considered too low for good agriculture. Similarly, total phosphorus (<5 mg/kg) were generally when compared to preferred levels of >10 mg/kg for good agriculture. The levels of sulphate were also low (<4 mg/kg) compared with recommended levels of >15 mg/kg for agricultural soils.

Exchangeable cations: The levels of sodium, potassium, calcium and magnesium varied widely between seasons and depths compared to control. All values were higher than the respective critical values for soil and are consider adequate for agricultural production but sodium was higher than the recommended limit of < 1.0 cmol/kg.

Heavy metals

Mercury, barium and vanadium were not detected in the soils of the study area. All other studied metals including copper, zinc, lead, cadmium, nickel, chromium and arsenic were generally very low in concentrations and within the recommended limits for agricultural soils. Only iron showed high concentrations at all locations and depths. Although iron was higher than the recommended limit of 500 ppm for good soils, high concentrations of iron in Niger Delta soils are a common occurrence and does not constitute any environmental hazard.

Aliphatic and Aromatic hydrocarbons

BTEX were not detected in the soils indicating absence of any recent petroleum pollution. PAH ranged from below detection limit at most locations during the wet and dry seasons to a maximum of 0.274 mg/kg recorded for Acenaphthalene in the wet season. Wet season levels were significantly higher than dry season concentrations at all study locations. During the wet season, six (6) PAH congeners were undetectable in the soil (Benzo(b)fluoranthrene, Benzo(a)pyrene, Benzo(k)fluoranthrene, Indeno (1,2,3) perylene, Dibenz(a, h)anthracene, Benzo(g,h,i) perylene). Apart from dibenz(a,h) anthracene and benzo (g,h,i) perylene which were not encountered in any of the samples, all other PAH congeners were detected during the wet season. The wide distribution of both the 3-4 ring polycyclics and the higher ring polycyclics is an indication of the mixed sources of hydrocarbons (petrogenic and pyrogenic) particularly during the wet season in the study area. Levels of PAH were generally low and below levels of concern in soils.

Soil Microbiology

The counts of bacteria and fungi encountered are normal for unpolluted environments in the Niger Delta. The ratio of HUB to THB which is commonly used as an indicator of petroleum pollution was markedly lower than the threshold of 10% (Atlas, 1982) at all locations indicating absence of petroleum pollution in the soils.

Land Use/ Land cover

The land cover of the Enwhe field comprises of water, primary forest, fallow lands, urban and industrial areas. The area occupied by water remained approximately the same across the three periods. It covered an area of 3.15 km² in 1988, 3.92 km² in 1999 and 3.74 km² in 2015. The little changes in area coverage can be ascribed to some areas that are seasonally flooded. The primary forest area decreased across the three periods. It covered an area of 61.8 km² in 1988 and decreased to 56.6 km² in 1999 which decreased further to 47.52 km² in 2015. This decrease is due to the conversion of the primary forest into fallow lands and built-up around the study area. The fallow lands increased across the three periods. It covered an area of 2.53 km² in 1988 and increased to 6.05 km² in 1999 and further increased to 9.51 km² in 2015. The increase in the land coverage is due to the deforestation of the primary forest into fallows because of increase in urbanisation and other developmental activities. Urban/Industrial/Bare Land class increased across the three periods. This class covered an area of 1.07 km² in 1988, increased to 1.98 km² in 1999 and increased further to 5.21 km² in 2015. This growth is observed around Obunaghan, Tombia, Gbarantoru and the SPDC CPF area. This is an indication of high urban development/construction and influx of people into the study area.

Groundwater quality

Physicochemistry

Ground water physicochemical parameters including pH, redox potential, conductivity, dissolved oxygen, BOD, COD, nitrate, phosphate, alkalinity, sulphate, cations, heavy metals and oil & grease were within recommended limits for drinking water. Turbidity and Total suspended solids were

above recommended limit of 10 NTU at all locations including the control particularly during the wet season (eg. Wet season control Mean: 38,590 NTU). This was attributed to the unconfined nature of surface aquifers which allows infiltration of surface materials. All measured physicochemical parameters showed a tendency to increase during the rainy season which is attributed to rain-related inputs from infiltration.

Microbiology

Levels of Total Heterotrophic Bacteria (THB), Hydrocarbon Utilizing Bacteria (HUB), Total Heterotrophic Fungi (THF) and Hydrocarbon Utilizing Fungi (HUF) were all within normal levels for the unpolluted surface waters. Coliform bacteria occurred widely (Mean:0.8-11 MPN/100 ml) making the waters hazardous to health and unsafe for human consumption

Vegetation

The vegetation in Enwhe was described in seven transects and two controls within the study area. The vegetation was divided into Flood forest, low land forest, secondary vegetation, agricultural and home gardens. The percentage composition of the vegetation showed that trees constituted 29.91%, herbaceous plants 14.53%, shrub 13.68%, climbers 8% and grasses 4%. Some of the trees identified in the area were *Hevea brasiliensis*, *Elaeis guineensis*, *Pentades matyracea*, *Anthocleista nobilis*, *Anthocleista djalonensis*, *Cleistopholis patens*, *Laccosperma secundiflorum* (codominant with and *Psidium guajava*. The herbaceous plants observed in the area include: *Clappertonia ficifolia*, *Panicum subalbidum*, and *Alchornea laxiflora*. Annual flooding occurs in Enwhe with sources from River Orashi and River Nun. The floods can reach a height of 4-5.5 feet and lasts for an average of 5 weeks. The vegetation in the flooded areas of Enwhe are destroyed after the floods recede. Farmland clearing, plantation agriculture and lumbering have contributed to the alteration of the vegetation in the area.

In the study area, agricultural farmland and home gardens comprise of plants belonging to the following Families: Moraceae, Caricaceae, Solanaceae, Musaceae, Rutaceae, Poaceae, Bromeliaceae and Myrtaceae which were represented by *Artocarpus communis* (Breadfruit) *Carica papaya* (Paw- paw), *Solanum melongena* (Garden egg), *Musa paradisiacal* (Plantain), *Citrus Sinensis* (Citrus), *Ananas Comosus* (Pineapple), and *Psidium guajavas* (Guava). Edible green leafy vegetables found in the study area belonged to the following Families: Asteraceae, Cucurbitaceae and Amaranthaceae; examples include *Veronia amygalatina*, (Bitterleaf) and *Telfera occidentalis* (Fluted pumkin). Twenty-three (23) timber species were identified in the study area. Trees constitute the natural biodiversity of the area and are therefore critical in the ecological balance of the freshwater swamp forest zone. Felling of trees for commercial purposes resulted in loss of valuable plant species and reduced species richness and evenness.

Some ecosystem services provided by the plants in the study area include food such as yam. Cassava, vegetables and fruits; medicinal plants such *Garcinia kola* (bitter kola) *Chromolaena odorata* and *Alchornea spp* (Christmas bush). Regulatory and supporting ecosystem services

provided by plants in the study area were nutrient recycling, shielding of soil from erosion, siltation control and evapotranspiration.

Wildlife

The wildlife in Enwhe showed remarkable diversity in both invertebrates and vertebrates. There was abundance of invertebrates such as arthropods and molluscs. The edible land snail *Archachatina marginata* were also abundant and were commercially exploited in the area. For Amphibians, *Bufo regularis* (African common toad) was common while *Litoria Caerulea* (tree frog) was rare. Reptiles such as *Pelusios niger* (West African black turtle), *Kinixys erosa* (Scattered back turtle) and *Python regius* (Royal Pythons) were rare. *Osteolaemus tetraspis* (Dwarf crocodile) and *Crocodylus niloticus* (Nile crocodiles) were rare because they were exploited for food. Common reptiles in the study area include wall gecko, skinks and Agama lizards. Diverse Avifauna such as cattle egret, pied crow, hornbill and black flycatcher were seen in the study location. These Farmland birds were either insectivores or grain eating birds.

There were 24 species of mammals recorded at Enwhe. They include rodents (Rodentia), primates (Primates), pangolins (Pholidota), carnivores (Carnivora), insectivores (Insectivora), and ungulates (Artiodactyla). The study indicated that most of the mammals were rare, vulnerable and threatened while just few were common. The deforestation of Enwhe forest has exposed the mammalian population to hunters, and this has ultimately led to loss of biodiversity.

The ecosystem services provided by the wild life include provision of meat; birds participate in fruit and seed dispersal; mollusk plays a major role in nutrient recycling; while the butterflies pollinate the crops.

Aquatic Ecology

Phytoplankton

Phytoplankton was composed of Bacillariophyceae, Chlorophyceae, Cyanophyceae, Dinophyceae and Euglenophyceae with Bacillariophyceae being the most dominant and abundant. This is normal for Niger Delta Rivers. However, the higher abundance of Phytoplankton during the wet season compared to dry season is not common but this was attributed to the higher levels of phytoplankton nutrients (nitrate, phosphate, silicate) in the wet season. Shannon diversity (Mean: 2.772-3.52) indicated an ecologically stable system that is only moderately stressed.

Zooplankton

The zooplankton was composed of Protozoa, Copepoda, Rotifera, Cladocera and Insecta with Rotifera being the most dominant. Such distribution is normal in Niger Delta Rivers. The higher

wet season abundance of zooplankton is linked to the phytoplankton which provides direct food source to zooplankton. Dominance, diversity and richness indices indicate a relatively stable system. The Shannon diversity index (Mean: 2.6306-2.993) indicates a stable system with only a moderate level of stress.

Macrobenthos

The macrobenthos was composed of Crustacea, Annelida, Plecoptera, Diptera and Coleoptera with Annelida and Diptera being the most abundant during the wet and dry seasons respectively. The distribution of zooplankton is normal in Niger Delta Rivers. The higher abundance during the wet season compared to dry season was attributed to increased levels of silt and clay in sediments during the wet season. Silt/clay presents a richer source of organic carbon and food for microbenthic fauna. Dominance, Diversity and Richness indices indicate a stable ecosystem. The Shannon diversity index (Mean: 1.386-2.407) however points to a greater level of stress in the benthic environment. This may be linked to the low levels of organic food source in the sediment particularly in the dry season when the sediments are dominated by sand.

Fisheries

The major occupation of the inhabitants of the community living along Orashi and Nun Rivers was fishing. It is artisanal fisheries because of the low level of investment. Their fishing gears were largely made of long setlines, circling nets and seine nets of different mesh sizes and the fishermen used dug-out canoes. The finfish comprised of 11 Families namely: Hepsitidae, Characidae, Channidae, Ariidae, Centropomidae, Carangidae, Anabantidae, Bagridae, Cichlidae, Clariidae and Citharinidae. The Characidae were the highest in species abundance and consisted of *Hydrocynus brevis*, *H. lineatus*, *H. forskalii*, *Alestes nurse*, *A. baremoze*, *A. longipinnis* and *Micralestes acutidens*. The Family Cichlidae was the second in the order of importance and the examples were *Hemichromis bimaculatus*, *H. fasciatus*, *Pelmatochromis guentheri*, *Tilapia zillii*, *Sarotherodon galilaeus*, *Tilapia heudelotii*, *T. mariae* and *Oreochromis niloticus*. Bagriidae was represented by *Bagrus bayad*, *B. filamentosus*, *Clarotes lanticeps* and *C. macrophthalmus*. Carangidae, Ariidae, Hepsitidae and Centropomidae were represented by one species each. There was no significant difference in fishes caught during the rainy season and dry season. The catch per unit effort is low indicating overexploitation of fisheries resource.

Social Profile

Stakeholder communities, Governance, Religious belief and Customs

Twenty-four (24) stakeholder communities from five (5) Clans covering Bayelsa and Rivers States were captured in this study. The clans covered in Rivers State are: Emughan in Abua/Odual Local Government Area; and Igbuduya and Engenni in Ahoada West Local Government Area. Those in Bayelsa State are: Gbaran and Epie. The communities of the study area generally have a 5-level pyramidal/hierarchical governance structure headed by a Paramount ruler followed by the Chiefs'/Elders' Council, the Community Development Committee (CDC), Youths and Women Groups and Community-based Organizations (CBOs), and the individual members. The

Paramount Ruler is known by various names depending on the Clan concerned: Ama-Okosuwei; Amanana-Owei; Obanekien, etc. Christianity and African Traditional religion are the two main religious beliefs of the people of the area. Shrines and sacred grounds exist in the communities which are highly venerated by the people.

Land Ownership and Land Use

In Nigeria, access to land either for commercial use only and/or for ownership can be through outright purchase, inheritance, lease, mortgage, etc. In the study area, access to land is usually by inheritance. Individual ownership of land is not very common as the local land market is still at its development stage; families and groups of families have custody of ancestral land.

However, when land is to be acquired by an organization, the community leadership serves as platform for all negotiations. Land in the area is used mainly for farming and fishing purposes. Other indigenous uses of land are: hunting, lumbering, harvesting of non-timber forest products, as well as housing.

Population and Socio-demographic Information

The population of the 24 communities in the Enwhe FDP area, according to the 1991 census was 52,608 people. Out of this number, 27,871 were males and 24,737 were females. In terms of sex distribution males were more than females in the area. Using an annual population growth rate of 2.8%, the National Population Commission projected the population of the area for 1996, 2002 and 2006 at 72,260; 73,694; and 75,492, respectively. As part of this study, the population of the area was projected for 2015 and 2030 using an annual growth rate of 3.4% and the exponential growth model. The projected population for 2015 and 2030 are 98,593 and 128,763, respectively.

Livelihood and Micro-economy

Agriculture, farming and fishing are major traditional economic activities within the communities. Common crops cultivated in the area include plantain, banana, cassava, okra, pepper, potato, etc. Other economic activities in the Project area include lumbering, harvesting of non-timber forest products, motor/tricycle transportation business, telecommunication, hair dressing, petty trading, etc. Income in the area range between N1,000.00 and N75,000.

Infrastructural Facilities and Quality of Life

Communities in the study area were observed to have one or more infrastructural facilities such as electricity, primary and secondary schools, roads, health care centers, town hall, market, jetty, and pipe borne water. However, not all the infrastructural facilities in the communities surveyed are in functional state. With respect to electricity supply, only Obunagha in the Gbaran Oil Field had regular power being supplied by SPDC from its flow station.

Housing and House Types

Housing in the Enwhe communities are a mixture of modern and traditional designs and construction materials. With the exception of communities in the Igbuduya Clan, houses in the other communities were observed to be clustered. The houses within the communities in Igbuduya Clan are separated by bush and patches of farm land. Houses with modern designs were built with improved utilities like kitchen, toilet and bath. Most houses in the communities were constructed with stable and permanent materials like cement blocks and roofed with corrugated iron sheets. However, in the Igbuduya, Ogbogolo and Abua/Odual areas, a good number of houses had roofs made up of corrugated iron sheets with mud or wooden walls. In Gbaran and Epie areas, most houses across the communities were bungalows and flats. The bungalows were built with many rooms and were mostly multi-tenanted. A few houses were built with single rooms or as self-contained units for commercial purposes. Bungalows account for more than 50% of houses in these communities.

Perceptions, Needs, Interests, Concerns and Expectations from Proposed Project

During the consultation meetings with the leadership of the communities in the Enwhe FDP area, several concerns and expectations were expressed. Communities in the area expressed displeasure at SPDC's posture with regards to employment of indigenes and the provision of basic infrastructure. They were particularly bitter that repeated studies have been carried out and their expectations (demands) articulated, yet nothing had done. They emphasized that SPDC should show human face and be more proactive in addressing community complaints. The communities expect that the Enwhe FDP would provide the SPDC the opportunity to turn a new leaf in its relationship with them such that their infrastructural and other challenges would be addressed.

Health Profile

Secondary data on health status of the communities within the study area was obtained from previous studies on Obunagha community around the Gbaran Central Processing Facility. The most common causes of ill health in the communities were said to be malaria, typhoid fever, upper respiratory tract infections, skin diseases and diarrheal diseases. These health problems reported by discussants at the FGD sessions held in the communities were comparable to the patterns noted in records of public health facilities that serve the various communities; and consistent with the diseases seen in other communities in Nigeria (NDHS, 2008).

Similar to situations in several rural communities in the Niger delta, the incidence of non-communicable diseases like hypertension and diabetes mellitus are beginning to rise in the communities. An indication of this was obtained during the focus group discussions conducted in the communities, and corroborated by the results of the random measurement of blood pressure carried out during the field study. Under-five and maternal mortality rates are falling within the communities. This was acknowledged during the focus group discussions held in the communities. The mortality rates in the communities were comparable to those of neighboring communities.

Reports of maternal mortality was said to be as low as once a year within the communities. This decrease in maternal mortality was attributed to the training of traditional birth attendants in the communities, and the swiftness with which emergencies were recognized and referred to hospital, for appropriate treatment. Causes of maternal deaths recorded in the communities within the last five years, according to discussants include prolonged labour, post-partum hemorrhage, abortion; and eclampsia. These causes are also consistent with the findings in most other communities in Nigeria (NDHS, 2008).

The common causes of under-five mortality include: malaria and its complications, especially anemia and febrile convulsion; gastro-enteritis (diarrhoea and vomiting), acute lower respiratory tract infection; and vaccine preventable diseases like measles.

Most of the communities, have a health facility located within the prescribed 5km distance, or 30-60 minutes travel time. The Primary Health Care facilities are either sited in the communities, or have the communities as part of their catchment area. Most of the health centers in the communities are however poorly equipped, and did not offer regular medical services. Pharmacies of health centers lacked essential drugs, mainly because they did not have a proper drug revolving scheme. The members of the Emughan clan access secondary health care services from the Aminigboko cottage hospital, built by SPDC but currently being managed by the Rivers State government.

In addition to primary and secondary health care centers, tertiary health care centers such as Niger Delta University Teaching Hospital, Okolobiri; Federal Medical Center, Yenagoa; and the University of Port Harcourt Teaching Hospital, Port Harcourt; are accessible to these communities. Similar to communities in the South-South region of Nigeria, alcohol and tobacco are commonly taken. The sexual behavior of members of the communities can encourage the transmission of sexually transmitted infections, including HIV/AIDS. Polygamy is common, most adult males have multiple sexual partners, and marital infidelity is culturally tolerated for men

ES. 19.0: Potential and Associated Impacts

The assessment of the degree of alteration to natural conditions of the environment viz-a-viz the project activities. However, the overall potential negative impacts of the project activities on the environment were generally minimal. The project activities which showed potential negative impacts include but not limited to the following:

- Movement of equipment and personnel, Rig movement
- Route & location clearing Dredging & Sand filling, Pilling, Concrete and asphalt works, Excavation, Backfilling, Pipeline coating, Stringing & welding; NDT and cathodic protection and Base camp activities.
- Drilling and well hook-up.
- Well & pipeline testing, Cathodic Protection.
- Commissioning & Handover
- Well work-over, Gas production, Pipeline maintenance & replacement.

- Flushing of pipelines, Vacuum drying of pipeline, capping of pipeline, Removal of surface installations, Plugging of wells.

The negative impacts will be generally minimal, localized and short-term, particularly given the fact that the adverse impacts will be properly mitigated with the strict implementation of the Environmental Management Plan developed for the proposed project. Significant negative impacts of the proposed project include but not limited to the following:

- Third party agitation
- Increase in road traffic, potential for accidents and injuries
- Loss of livelihood
- Damage to road infrastructure
- Influx of people causing Pressure on health and other Infrastructure
- Reduction in air quality
- Loss of aquatic species (Fisheries, Planktons and benthic fauna)
- Increase in noise and vibration
- Increase in refined hydrocarbon contents of soil and vegetation
- Increase in crime rate
- Contamination of groundwater.

Positive impacts of the proposed project include but not limited to the following:

- Potential for skills acquisition
- Opportunity for direct and indirect Employment
- Opportunity for wealth creation
- Potential for development of infrastructures and economic enhancement.

ES 20: Mitigation Measures

To ensure that all negative impacts are reduced to the barest minimum in the execution of the Enwhe Field Development Project, the following mitigation measures shall be applied:

- SPDC shall ensure adequate consultation with all stakeholders especially communities
- SPDC shall carry out sound community sensing to evaluate existing relationship between SPDC & fence line communities, collate legacy projects & agree with community on ways of addressing them to change the perception to positive.
- Land take shall be limited to the minimum required.
- Stakeholder's engagement shall be sustained through the project lifecycle.
- SPDC shall discuss and agree on sustainable community development project and implement agreed projects, these will serve the whole fence line communities without bias.
- Relevant stakeholders/legacy issues shall be identified
- Regular consultation with stakeholders (Govt., Community, NGOs, CBOs etc.) shall be carried out to understand community perceptions, issues and concerns

- Alternative income generating activities through skills acquisition that will empower communities shall be introduced and supported.
- SPDC shall ensure all project vehicles observe the speed limits and large vehicles have warning lights to alert other road users.

E.S 21.0: Environmental Management Plan

The Environmental Management Plan (EMP) provides a general overview of each of the major EMP components, as well as the guidelines and procedures for managing the significant impacts of the Project. An Environmental Monitoring Plan has also been developed from the EMP. It will ensure adequate monitoring key receptors and waste streams in the Iseni field. The EMP shall be used to ensure that potential adverse effects are reduced to ALARP levels. The EMP shall also be used to check and continuously monitor compliance and effectiveness of the mitigation and enhancement measures. These are outlined in the EIA report that SPDC has committed to implement for the Project. In addition, this EMP shall be used to ensure compliance with statutory requirements and corporate safety, health and environmental plans of SPDC. The primary objective of the EMP is to provide a set of consistent managerial tools, which will enable SPDC to monitor and control environmental performance.

E.S 21.0: Conclusion

The Environmental Impact Assessment Studies of the Enwhe Field Development Project was carried out in accordance with relevant local, national and international regulations. The methodology applied for the study involved field work, laboratory analyses, review of previous reports and current field data within the area. To achieve this objective, a multi-disciplinary approach was adopted in the assessment of the environmental status and sensitivities of the various biophysical components. The Enwhe Field Development Project is an opportunity to sustain gas supply to NLNG and maximize utilization of Gbaran CPF by developing gas and condensate in the Enwhe field. Other positive impacts of the proposed project include but not limited to the following: increase in business opportunities, provide Opportunity for direct and indirect Employment (Unskilled labour) and Opportunity for contracting.

The identified adverse impacts were generally short-term and can be prevented, reduced, ameliorated, or controlled if the recommended mitigation measures are implemented. An Environmental Management Plan and a Monitoring Plan have been developed to ensure that the identified potential impacts are reduced to “as low as reasonably practicable” (ALARP). The EMP should therefore form the basis for the actual project implementation and future monitoring of environmental components. The approval of this EIA report for the execution of the proposed project is hereby recommended.

Acknowledgement

The Shell Petroleum Development Company of Nigeria Limited wishes to express sincere appreciation to the Department of Petroleum Resources, Federal Ministry of Environment (FMEnv), Bayelsa and Rivers State Ministry of Environment for their support, advice and invaluable assistance throughout the period of this study. The efforts of our environmental consultants, relevant Non-Governmental Organizations (NGOs) and Community Based Organizations (CBOs) are also highly commendable. Finally, we give special thanks to the Paramount Rulers, Clan Heads, Village Heads, Women and Youth Groups, Local Government Councils, etc. for their co-operation and willingness to express their views, concerns as well as expectation

CHAPTER ONE INTRODUCTION

1.1: Background Information

The Shell Petroleum Development Company of Nigeria Limited (SPDC), on behalf of its Joint Ventures partners (Nigerian National Petroleum Corporation, Total, and Nigeria Agip Oil Company) conducted an Environmental Impact Assessment study for the Enwhe Field Development Project. The Enwhe field development project is an opportunity to sustain gas supply to NLNG and maximize utilization of Gbaran CPF by developing gas and condensate in the Enwhe field. The Enwhe field is part of the phased development of Gbaran node to support SPDC's gas supply obligation of 2bscf/d to NLNG; and also grow oil production in Gbaran node. The proposed development in the Enwhe field will involve the drilling of gas and oil wells from two surface locations, construction of oil and gas pipelines and manifolds to tie the field into the Greater Gbaran Infrastructure. The development strategy in the Enwhe field will be in two tranches. Tranche-1 (i.e. this project) is focused on gas, while Tranche-2 is oil and gas development after appraisal for oil in Tranche-1.

The proposed activities for the development of the Enwhe field will have various interactions with the environment, hence the need to conduct an Environmental Impact Assessment (EIA) study. In line with the provisions of Part VIII – Section A, 3.0 of the Environmental Guidelines and Standards for Petroleum Industries in Nigeria, 2002 (EGASPIN), an environmental screening of all concept options and a preliminary assessment of the selected option was conducted and approval issued (Appendix 1.1). Post approval of the environmental screening and preliminary impact assessment report, the Terms of Reference/Scope of Work (ToR/SoW) was submitted to the Department of Petroleum Resources (DPR) and Federal Ministry of Environment (FMEnv) for consideration and an approval obtained (Appendix 1.2 and 1.3). This EIA study has identified the key potential impacts of the project activities on Biophysical, Social and Health components within the project area and proffered mitigation measures for Environmental Management. The findings are hereby incorporated in this report.

1.2: Objectives of the Environmental Impact Assessment

The objectives of the Environmental Impact Assessment study for Enwhe Field Development Project include but not limited to the following:

- Acquire baseline data of the environment as well as the socio-economic and health conditions of the host communities;
- Use the baseline data to describe and characterize the study area;
- Identify the environmental sensitivities of the project area;
- Determine and evaluate the potential impacts of the proposed project activities on the identified environmental sensitivities and the interactions between the sensitivities;
- Recommend appropriate mitigation measures; and
- Develop an Environmental Management Plan (EMP).

1.3 Project Location

The Enwhe field is located in the south-western corner of license block OML 22 and extends into license block OML 23 and is located about 36km to the East of Gbaran CPF. The field is part of the Gbaran Ubie Node which is a multi-field oil and gas asset. The Enwhe field is bounded by creek and creeklets of Orashi and Nun River. Major communities in the Enwhe field lies in Yenagoa Local Government Area of Bayelsa State and Ahoada West and Abua/Odual Local Government Areas of Rivers State (Table 1.3.1).

Table 1.3.1: Major communities in the Enwhe field in Rivers and Bayelsa States

S/N	State	LGA	Clan	Community
1	Rivers state	Abua/Odual	Emughan	Aminigboko
				Owerewere
				Emesu
				Okoboh
				Emabu
				Obarany
				Egunughan
		Ahoada West	Igbuduya	Obodhi
				Ogbologbolo
				Ogbede
				Odieke Ugbobi
				Odigwe
			Engenni	Ogbogolo (Ogbogolo, Opu Ogbogolo, Kala Ogbogolo, Egboama Ogbogolo)
				Akiogbologbo
				Ikodi Engenei
				Okarki
				Kunushia
2	Bayelsa State	Yenagoa	Gbaran	Okolobiri
				Obunagha
			Epie	Okutukutu
				Agudama-Epie
				Kumboama
				Akenfa

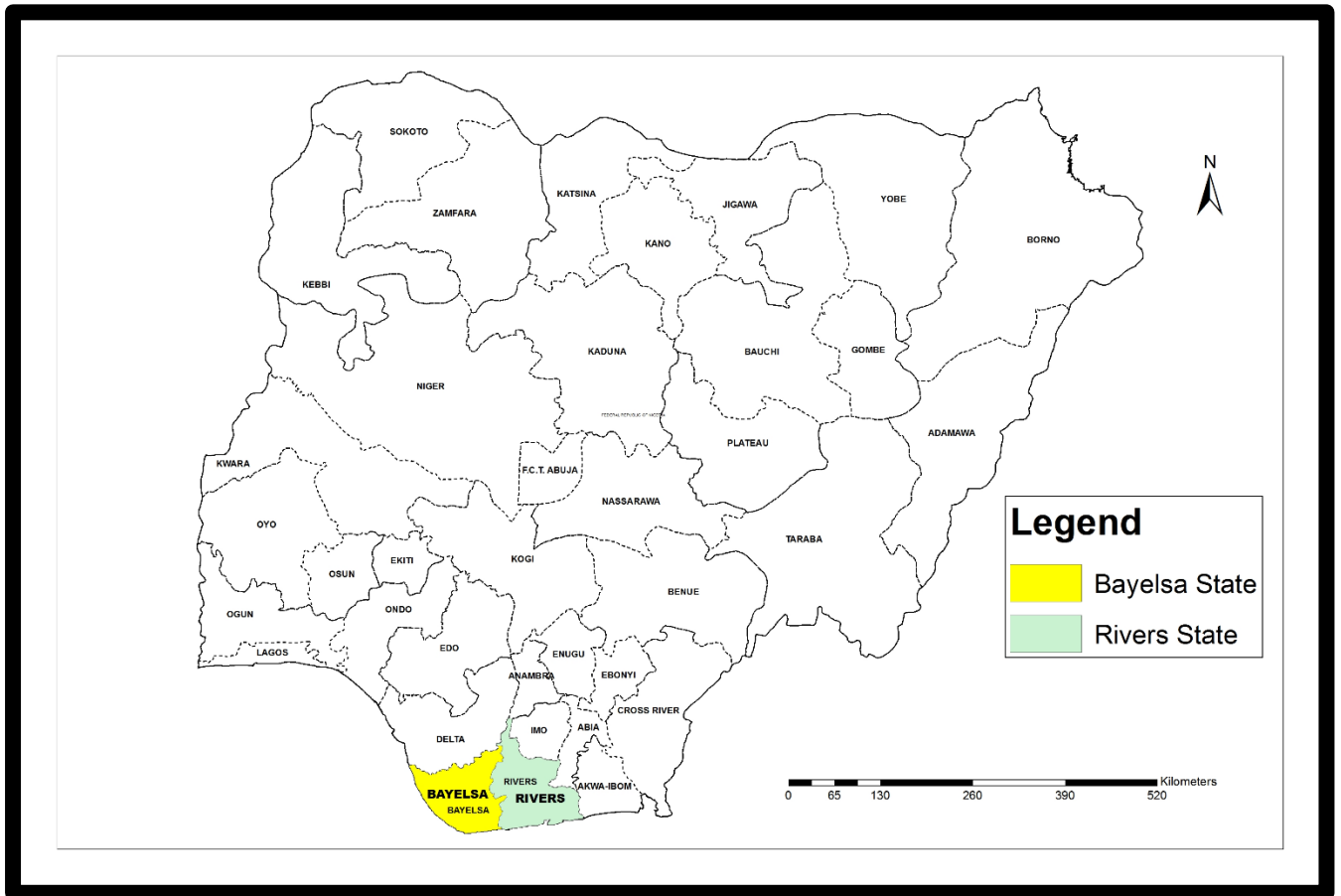


Fig 1.3.3 Map of Nigeria showing Rivers and Bayelsa States

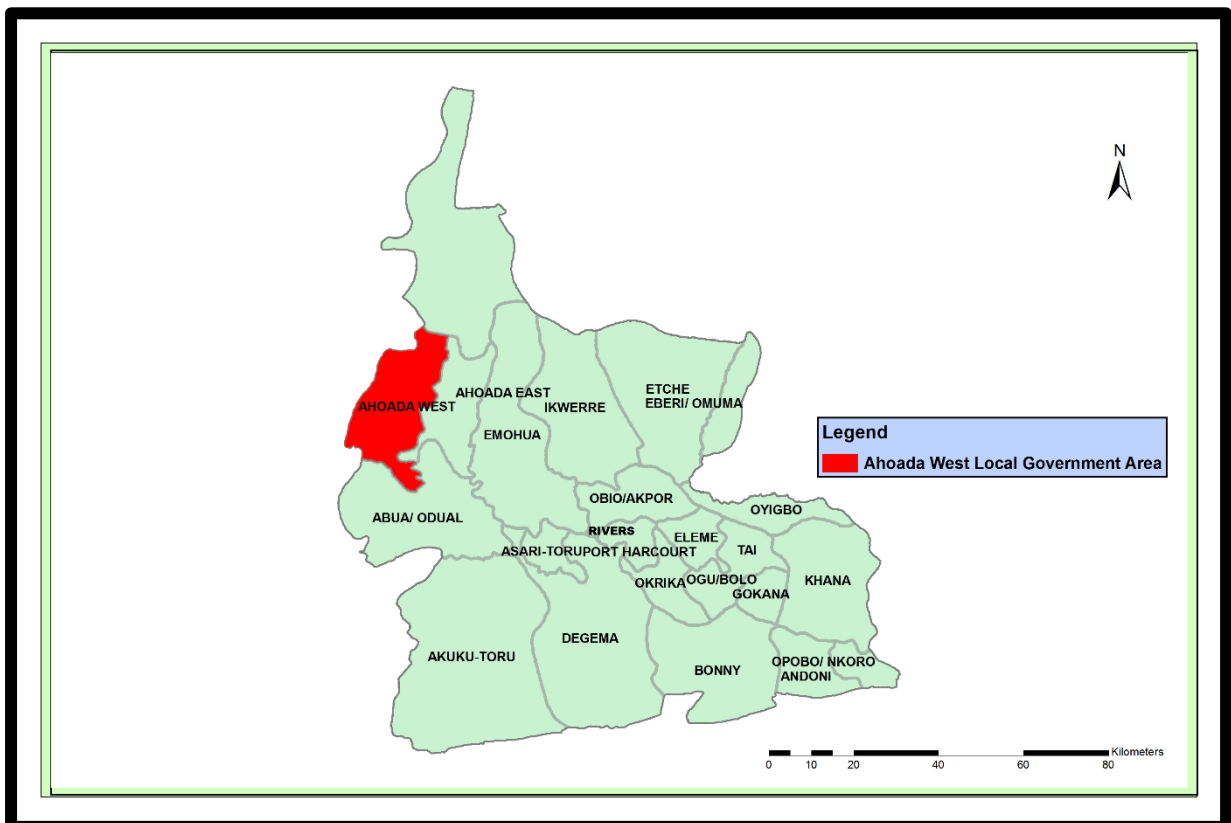


Fig. 1.3.1a: Map of Rivers State showing Ahoada West Local Government Area

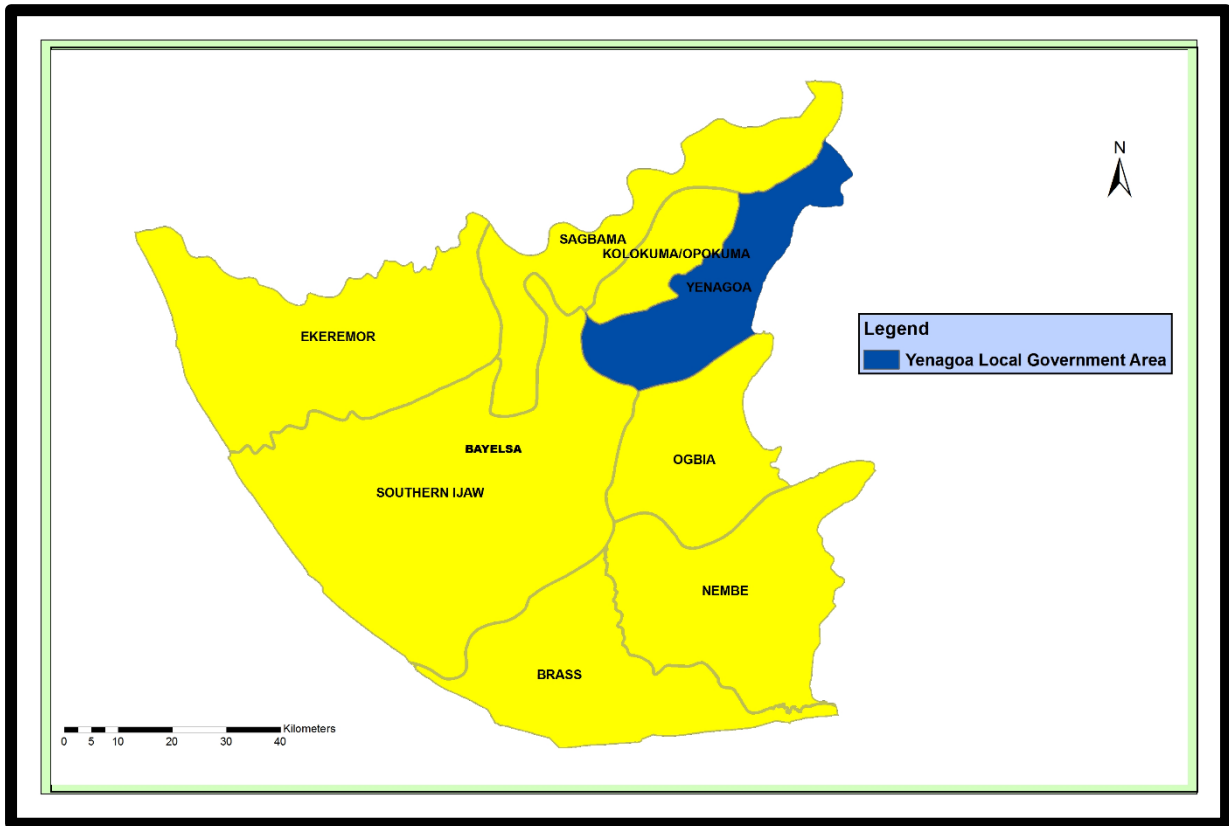


Fig. 1.3.1b: Map of Bayelsa state showing Yenagoa Local Government Area

1.4: Legal and Administrative Framework

There are legislations, guidelines and standards that govern the assessment of environmental impacts of development projects in the oil and gas industry in Nigeria. These regulations can be classified as follows:

1.4.1: Legislations guiding Environmental management in Nigeria

The Mineral Oil (Safety) Act CAP 350 LFN 1990

Sections 37 and 40 of the Mineral Oil (Safety) Act CAP 350 LFN 1990 require provision of Personal Protective Equipment (PPE) and the safety measures for workers in drilling and production operation in accordance with international standards.

Federal Environmental Protection Agency (Now FME_{env}) Act No. 58, 1988

This Act, which was issued in 1988 and amended by Act No. 59 of 1992, provides the setting up of the Federal Environmental Protection Agency, as the apex organization for the overall protection of the Environment and Conservation of Natural Resources. The act also makes environmental impact assessment (EIA) mandatory for all new major projects. In compliance with its mandate, FEPA issued the procedure, guidelines and standards for the execution of EIA with emphasis on the significance associated with current and potential impacts of such

projects. The procedure also indicates the steps to be followed (in the EIA process) from project conception to commissioning in order to ensure that the project is executed with adequate consideration for the environment.

EIA Sectoral Guidelines for Oil and Gas Industry Projects, 1995

In compliance with its mandate, FEPA issued the EIA Sectoral Guidelines for Oil and Gas Industry Projects, 1995. Contained in the Procedural Guidelines (pg. 8) are Category I projects (mandatory study activities) and listed under item 15, sub-item (a) on page 10) (Petroleum) is Oil and Gas Fields Development, making an EIA mandatory for the proposed project. The Procedural Guidelines also indicate the steps to be followed (in the EIA process) from project conception to commissioning in order to ensure that the project is executed with adequate consideration for the environment. Annex C contains the EIA writing format as required by FMEnv. The guidelines are intended to assist in the proper and detailed execution of EIA studies of projects in consonance with the EIA Act.

S.I. 15 - National Environmental Protection Management of Solid and Hazardous Wastes Regulation (1991) (FMEnv)

This provides that the objective of solid and hazardous waste management shall be to:

- Identify solid, toxic and extremely hazardous wastes dangerous to public health and environment,
- Provide for surveillance and monitoring of dangerous and extremely hazardous wastes and substances until they are detoxified and safely disposed,
- Provide guidelines necessary to establish a system of proper record keeping, sampling and labelling of dangerous and extremely hazardous wastes,
- Establish suitable and provide necessary requirements to facilitate the disposal of hazardous wastes;
- Research into possible re-use and recycling of hazardous wastes.

Environmental Impact Assessment Act CAP E12 LFN 2004

The Act sets out general principles, procedures and methods to enable the prior consideration of Environmental Impact Assessment on certain public or private projects. The objectives of the Act is to promote the implementation of appropriate policies consistent with all the laws and decision making processes through which the goal and objectives maybe realized. The Act also encourages the development of procedures for information exchange, notification and consultation between the organs and persons when proposed projects or activities are likely to have significant environmental effects on boundary or trans-state or on the environment of bordering towns and villages.

FEPA (Now FMEnv) Nigeria's National Agenda 21 (1999)

Nigeria's National Agenda 21 was developed to:

- Integrate environment into development planning at all levels of government and the private sector,
- Intensify the transition to sustainable development,

- Address sectoral priorities, plans, policies and strategies for the major sectors of the economy and,
- Simultaneously foster regional and global partnerships.

FEPA (Now FMEnv) National Policy on the Environment (1989)

This gave the policy goals, conceptual framework and strategies for implementation.

Forestry Law CAP 51 LFN 1994

The Forestry Act 1958 which was amended as the Forestry Law CAP 51 LFN 1994 prohibits any act that may lead to the destruction of or cause injury to any forest produce, forest growth or forestry property in Nigeria. The law prescribes the administrative framework for the management, utilization and protection of forestry resources in Nigeria, which is applicable to the mangrove, and other forests of the Niger Delta.

Land Use Act CAP 202 LFN 1990

The land-use Act of 1978 states that “... it is also in the public interest that the rights of all Nigerians to use and enjoy land in Nigeria in sufficient quality to enable them to provide for the sustenance of themselves and their families should be assured, protected and preserved”.

National Inland Waterways Authority Act No 13 of 1997

This Act established the National Inland Waterways Authority with a view to improving and developing inland waterways for navigation, providing an alternative mode of transportation for the evacuation of economic goods and persons, executing the objectives of the national transport policy as they concern inland waterways. The Act also prescribes regulations and sanctions on the use and exploitation of resources of inland waterways such as dredging, sand or gravel, mining and erection of permanent structures within the right-of-way or diversion of water from a declared waterway.

National Oil Spill Detection and Response Agency Act 2006 as amended

This act established the National Oil Spill Detection and Response Agency with a view of coordinating and implementing the national oil spill contingency plan and establishing mechanism to monitor and assist, or where necessary, directing the response. NOSDRA basically provides oversight function for oil spill detection, reporting and response in Nigeria.

Endangered Species Act CAP E9 LFN 2004

This Act prohibits hunting, capture and trade of some *endangered species* like crocodile, alligator, turtles, Parrot, etc. The Endangered (Control of International Trade and Traffic) Decree (No. 11 of 1985) has been enacted by the Federal Republic of Nigeria specifically to implement CITES. It is broader than CITES in that it also covers domestic taking of listed species. Two schedules are included: Schedule I (Endangered Species – Animals in relation to which International Trade is absolutely Prohibited), and Schedule 2 (Animals in Relation to which International Trade may only be conducted under License). The decree prohibits taking

of Schedule 1 species and requires that taking of Schedule 2 species be in accordance with a license issued under the decree.

Petroleum Act CAP 350 LFN 1990

An Act to provide for the exploration of petroleum from the territorial waters and the continental shelf of Nigeria and to vest the ownership of, and all on-shore and off-shore revenue from petroleum resources derivable therefrom in the Federal Government and for all other matters incidental thereto.

Territorial Waters Act CAP 428 LFN 1990

The territorial waters of Nigeria shall for all purpose include every part of the open sea within twelve nautical miles of the coast of Nigeria (measured from low water mark) or of the seaward limits of inland waters. Any act or omission which-

- (a) is committed within the territorial waters in Nigeria, whether by a citizen of Nigeria or a foreigner; and
- (b) would, if committed in any part of Nigeria, constitute an offence under the law in force in that part, shall be an offence under that law and the person who committed it may, subject to section 3 of this Act, be arrested, tried and punished for it as if he had committed it in that part of Nigeria

Water Resources Act CAP W2 LFN 2004

The Water Resources Act vests the right to the use and control of all surface and groundwater and of all water together with the bed and banks in any watercourse affecting more than one state in the Government of the Federation. However, the Act essentially preserves existing rights, including customary rights, provided they are for domestic use, watering of livestock and personal irrigation schemes. A proviso to section 1(1) states that the subsection shall not be deemed to infringe or to constitute a compulsory right over or interest in property. Apparently, the idea is to separate rights over water resources from other rights in property.

Nigerian Oil and Gas Industry Content Development Act 2010

The Act provides for the development of Nigerian Content in the Nigerian Oil and Gas Industry, Nigerian Content Plan, Supervision, Coordination, Monitoring and Implementation of Nigerian content and for related matters. All regulatory authorities, operators, contractors, subcontractors, alliance partners and other entities involved in any project, operation, activity or transaction in the Nigerian oil and gas industry shall consider Nigerian content as an important element of their overall project development and management philosophy for project execution.

Employee's Compensation Act No. 13, 2010

The objectives of the Act are to— (a) provide for an open and fair system of guaranteed and adequate compensation for all employees or their dependants for any death, injury, disease or disability arising out of or in the course of employment ; (b) provide rehabilitation to employees with work-related disabilities as provided in this Act ; (c) establish and maintain a solvent compensation fund managed in the interest of employees and employers ; (d) provide for fair and adequate assessments for employers ; (e) provide an appeal procedure that is simple, fair

and accessible, with minimal delays ; and (f)combine efforts and resources of relevant stakeholders for the prevention of workplace disabilities, including the enforcement of occupational safety and health standards.

1.4.3: Legislations guiding Environmental management in Bayelsa State

The Bayelsa state regulations guiding Environmental management includes but not limited to the following:

- Bayelsa State Environmental and Development Planning Authority Law 1998;
- Bayelsa State Pollution Compensation Tax Law 1998;
- Bayelsa State Forestry Law 1998.

1.4.4: Legislations guiding Environmental management in Rivers State

- Rivers State Environmental Protection Agency Law No. 2 of 1994
- Rivers State Private Health and Allied Establishments Authority Law, 2001
- Rivers State Public Health Law, 1999
- Rivers State Noise Pollution Control Law of 1984

1.4.2: International Laws and Regulations

Nigeria is signatory to several laws, treaties and regulations that govern the environment.

Among these are:

- (i) World Bank Guidelines on Environmental Assessment {EA} (1991)
- (ii) International Union for Conservation of Nature and Natural Resources (IUCN) Guidelines
- (iii) Convention on the Migratory Species of Wild Animals (Bonn Convention)
- (iv) Convention of Biological Diversity
- (v) Convention Concerning the Protection of the World Cultural and National Heritage Sites (World Heritage Convention)
- (vi) Basel Convention on the Control of Trans-Boundary Movements of Hazardous Wastes and their Disposal and.
- (vii) United Nations Framework Convention on Climate Change (1992)

World Bank Guidelines on Environmental Assessment {EA} (1991)

The World Bank requires the execution of an EIA on a proposed industrial activity by a borrower as a pre-requisite for granting any financial assistance in form of loans. Details of World Bank's EIA procedures and guidelines are published in the Bank's EA Source Book vols. I - III of 1991. Potential issues considered for EA in the upstream oil and gas industry include the following:

- Biological Diversity
- Coastal and Marine Resources Management
- Cultural Properties
- Hazardous and Toxic Materials and
- International waterways.

International Union for Conservation of Nature and Natural Resources (IUCN) Guidelines, 2001

The IUCN in conjunction with the Oil Industry International Exploration and production Forum presented a set of guidelines for oil and gas exploration and production in mangrove areas. These guidelines are aimed at conservation of mangroves and enhancing the protection of marine ecosystems during E & P activities. The document also discusses the policy and principles for environmental management in mangrove areas as well as EIA procedures, Environmental Audit and Monitoring.

Convention on the Conservation of Migratory Species of Wild Animals (Bonn Convention), 1979

The Bonn Convention concerns the promotion of measures for the conservation and management of migratory species.

Convention on Biological Diversity, 1992

The objectives of the Convention include the conservation of biological diversity, the sustainable use of its components, and the fair and equitable sharing of benefits arising out of the utilization of genetic resources.

Convention Concerning the Protection of the World Cultural and Natural Heritage Sites (or World Heritage Convention), 1972

The convention sets aside areas of cultural and natural heritage for protection. The latter is defined as areas with outstanding universal value from the aesthetic, scientific and conservation points of view.

Basel Convention on the Control of Trans-Boundary Movements of Hazardous Wastes and their Disposal, 1989

The convention focuses attention on the hazards of the generation and disposal of hazardous wastes. The convention defines the wastes to be regulated and control their trans-boundary movement to protect human and environmental health against their adverse effects.

United Nations Framework Convention on Climate Change (1992)

In order to achieve sustainable social and economic development, energy consumption for developing countries needs to grow taking into account the possibilities for achieving greater energy efficiency and for controlling greenhouse gas emissions in general. This also includes the application of new technologies on terms which make such an application economically and socially beneficial, determined to protect the climate system for present and future generations.

1.4.5: SPDC Policies and Principles

Shell Petroleum Development Company (SPDC) operates under the guidelines of Shell International and complies strictly with them. Where national standards and regulations are more stringent than Shell guidelines, SPDC's policy is to comply with the existing national legislation.

(a) Business Principles

Shell companies have a systematic approach to health, safety, security and environmental management in order to achieve continuous performance improvement. To this end, Shell companies manage these matters as critical business activities, set standards and targets for improvement, and measure, appraise and report performance externally.

(b) Governing Policies

The SPDC 1998 Corporate Policies emerged with five Business Governing policies. Of interest to this document is the section on HSE referred to as ‘Health, Safety and Environment Policy’. This policy addresses the health, safety, and environmental risks to the business and the potential impacts on staff, personnel, and the host communities. The policy reflects good practice and is mandatory.

(c) HSE Policy

It is SPDC’s Policy that all activities shall be planned and executed in a manner that,

- Preserves the health, safety and security of all Company and contractor personnel and members of the public;
- Preserves the integrity and security of Company assets;
- Minimizes the impact of operations on the environment; and
- Is sensitive to the needs and concerns of the Host Communities.

The implications of implementing this policy are that,

- All activities shall be analyzed to systematically identify related hazards, risks and sensitivities;
- Arrangements shall be put in place to control the hazards, risks and sensitivities and to deal with consequences should they arise;
- Any activity which is unhealthy, unsafe, environmentally unsound or may adversely impact relations with the community, shall be suspended until an acceptable solution is found;
- All personnel, including those of contractors, shall be trained and made fully aware of the hazards, risks, sensitivities and controls in place; and
- Plans and procedures shall be in place to respond to any emergency or loss of control.

Every employee and contractor employee must plan and perform his work in accordance with this policy. Each employee is required to report, and where necessary, suspend any activity considered to be in contravention of this policy.

(e) SCiN Biodiversity Policy

‘In Shell, we recognize the importance of biodiversity. Therefore, we are committed to:

- Work with others to maintain Ecosystems
- Respect the basic concept of Protected Areas

- Partner with others to make positive contributions towards the conservation of biodiversity in our areas of operations
- Conduct Environmental Assessments with increased focus on impacts on biodiversity
- Engage and collaborate with other stakeholders to manage biodiversity responsibly especially in sensitive environments ‘

(f) Waste Management Policy

It is the policy of SPDC to:

- Take all practical and reasonable measures to minimize the generation of solid and liquid wastes, as well as emissions from construction equipment and otherwise;
- Manage and dispose off wastes in an environmentally responsible manner;
- Track and maintain records of waste streams and provide an auditable trail as to their management and disposal.

(g) Emergency Response Policy

This states that the response to any emergency within SPDC will be directed towards

- Saving life
- Care for the injured
- Protection of the environment
- Limitation of damage to assets
- Defence of SPDC’s good corporate image
- SPDC shall provide appropriate organization, facilities, procedures and training so that immediate coordinated action can be taken to manage the situation in line with the above
- Maintenance of emergency equipment shall receive high priority. Close liaison will be maintained with appropriate Government and industry organization and communities
- Regular exercises will be carried out to confirm effectiveness, and any necessary improvements made promptly so as to maintain our readiness at all times.

(h) Community Relations Policy

In order to pursue mutually beneficial relations with host communities, SPDC shall:

- Establish and maintain close relationships with all segments of the local population to better understand their concerns, needs and aspirations
- Continuously assess and abate social and economic impact of all business activities and take needed preventive or mitigating measures
- Respond to formal community request in an appropriate and timely manner
- Bring relevant issues affecting host communities to the attention of appropriate authorities and other bodies that can be of assistance
- Manage settlement of compensation for land acquired for company operations and for damages in a demonstrably fair, accountable and transparent manner and in accordance with statutory provisions and approved procedures.

1.5: Declaration

Shell Petroleum Development Company (SPDC) in its capacity as the operator of the Enwhe field hereby declares her intention to abide by the existing international and national laws and regulations regarding environmental protection during the Project phases. Shell Petroleum Development Company (SPDC) is committed to the implementation of the Environmental Management Plan (EMP) covering the Enwhe field. Shell Petroleum Development Company (SPDC) avows that it has prepared this EIA report using the best available expertise in personnel, equipment and internationally acceptable methods.

1.6: Structure of the EIA

The structure of the Environmental Impact Assessment Report presented below

- **Chapter One** - Introduction presents the background information, EIA objectives, Legal and administrative framework.
- **Chapter Two** - Project Justification, discusses the project background, project objectives, rationale for the project, envisaged sustainability, and development options considered;
- **Chapter Three** - Project Description, describes the type of project, scope, location, material input/output and by-products, waste generation, technical layout and process, operation and maintenance, project schedule;
- **Chapter Four** - Description of Existing Environment - provides information on the baseline environmental conditions of the project area describing the physical, chemical, biological, social, and health aspects of the environment
- **Chapter Five** - Associated and Potential Environmental Impacts - highlights the Associated and Potential Environmental Impacts of the proposed project;
- **Chapter Six** – Mitigation Measures/Alternatives – describes the mitigation options of impacts;
- **Chapter Seven** - Environmental Management Plan - provides the proposed plans for environmental management;
- **Chapter Eight** -Remediation plans after decommissioning/closure
- **Chapter Nine** - Conclusion and Recommendations
- **Appendices**
- **References**

CHAPTER TWO

PROJECT JUSTIFICATION

2.1: Introduction

The Enwhe field is part of the Gbaran Phase-3 developments in continuation of the planned phased development of the Gbaran node to supply gas and grow oil production. This chapter highlights the need for the projects in the Enwhe field, Value of the project, Project sustainability, Project options and alternatives.

2.2: Need for the Project

The Enwhe field development is expected to develop 767 Bscf of gas and 7 MMstb of condensate of the total field recoverable volume of 834 Bscf of gas and 15 MMstb of (oil and condensate), within the expected production life of the Gbaran CPF. The value drivers identified for the Enwhe FDP include but not limited to the following:

- Meet NLNG Gas Supply obligation - sustaining the planned DCQ as long as possible.
- To improve the recovery factor in the node towards the Top Quartile bracket.
- Reduced CAPEX - achieving low unit development cost to align with Partners aspiration
- and facilitate funding.
- Reduced OPEX - achieving low unit operating cost by utilizing remote operations capability to cut down on operator intervention and exposure considering remoteness of Enwhe field from Gbaran CPF.

2.3: Value of the Project

The revenue that will accrue from the sales of gas to be produced from these wells will substantially increase the foreign exchange earnings of the Federal Government and help to improve the social and health standards of the inhabitants of the area covered by the project. The 100% JV P50 cost estimate for Enwhe Tranche-1 development approximately 450 mln USD (Wells =200 mln and Facilities = 250mln).

2.4: Envisaged Sustainability

The proposed Enwhe FDP consists of gas development (Tranche-1), and oil & gas development (Tranche-2). The Enwhe field development project is an opportunity to sustain gas supply to NLNG and maximize utilization of Gbaran CPF by developing gas and condensate in the Enwhe field. The Enwhe FDP is envisaged to be sustainable (Environmental, Technical, Economic and Social) the and details presented in this subsection.

2.4.1: Economic Sustainability

A long term gas sale agreement (GSA) is in place that commits SPDC to supply an average Daily Contractual Quantity of 1,941 MMscf/d to the six NLNG train. It is an opportunity to sustain gas supply to NLNG and maximize utilization of Gbaran CPF by maturing 0.83Tcf of recoverable gas and 15MMbbls of oil and condensate. The Enwhe field has proven reserves of

gas that can economically and commercially support the project thereby contributing to the revenue accruing to Nigeria and SPDC.

2.4.2: Technical Sustainability

This project is technically sustainable because of SPDC's proven oil and gas technology and strict adherence to internationally and nationally acceptable engineering design and construction standards. Innovative technologies that are economically viable and having minimal environmental, social and health impacts shall be utilised in the execution of the proposed project. New gas wells will be drilled and flowlines constructed to transport the gas to a gathering manifold, from which the gas will be transported via a bulk line to the Central Processing Facility (CPF). The CPF has gas dehydration facilities for high pressure AG and NAG treatment prior to export to NLNG.

2.4.3: Environmental Sustainability

National and international regulatory and engineering design standards, innovative technologies that have minimal environmental, social and health impacts shall be utilized in the execution of the proposed project. The incorporation of the findings and recommendations of this report at the various stages of the project development and strict adherence to the Environmental Management Plan (EMP) will ensure environmental sustainability.

2.4.4: Social Sustainability

The integration of appropriate social impact assessment and community interface management mechanisms in the Project are critical success factors to the realization of overall business objectives and SPDC corporate reputation in the area. A stakeholder engagement plan has been developed and all stakeholders, especially communities, partners, regulators and other government agencies will be engaged in a proactive and respectful manner to engender participation and secure enabling environment for the Project. The deployment of GMoU and allied processes for interface management and delivery of basic community development intervention projects and programs is critical to the success of this project. Its scope will ensure that we do not create legacy issues, but enhance community participation in the business through active collaboration with SPDC Community Content Team. Skills will also be developed and business supported to enable community participation in the project execution phase and beyond. Approximately, 2.5% of project cost (CAPEX) shall be provided for the implementation of Social Performance intervention programs and projects in the impacted communities. The fund assigned for community development through the GMoU shall be paid into a joint account maintained with the communities in tranches and spread over the duration of the agreement, which will also align with the duration of that project.

2.5: Relationship with other field

There will be two well locations, namely Enwhe East and Enwhe West with three NAG wells per location with 6" flowlines. The three NAG wells in the East will be hooked up to a manifold in the East location and then bulk flowed to the Enwhe West manifold via a 12" Carbon Steel circa 5.5km. The three NAG wells in the West location will be hooked up to the Enwhe West manifold which will be installed near the Enwhe West cluster well location. The combined

flow from the six wells will be bulk flowed from Enwhe West manifold via a 36 km long, 12-inch bulkline to the Gbaran CPF (Gbaran field).

2.6: Project Options

This section presents the various development concepts for the Enwhe field opportunity. The concept that holds the most value for the opportunity was selected. The project options are presented in Table 2.1.

Table 2.1: Project options for the Enwhe FDP

Project Options	Advantages	Disadvantages	Remarks
<p>No Project Option: This option entails not implementing the project.</p>	<ul style="list-style-type: none"> No impact on Environment No new risks 	<ul style="list-style-type: none"> Stakeholders will not be able to increase their oil production target. The Economic opportunities (commerce, employment, etc.) for the communities will be lost. Huge investments that have already been committed into preliminary activities would be lost. 	Not recommended
Delayed Project Option	<ul style="list-style-type: none"> More time to plan and assess risks 	<ul style="list-style-type: none"> This will lead to a delay in achieving FID; Loss of expected revenue for the period of delay; Low capacity utilization of Gbaran CPF. 	Not recommended
Develop the Enwhe field	<ul style="list-style-type: none"> Increase the foreign exchange earnings of SPDC/Nigerian government. Optimal utilization of the Gbaran CPF. Meet NLNG Gas Supply obligation. Boost local economy of communities within the Enwhe field. Provide Technology transfer to locals. 	<ul style="list-style-type: none"> Increase SPDC environment footprint. High Unit Technical Cost (UTC). 	Recommended

2.6.1: Development Alternatives of the Enwhe FDP

The development alternatives/concepts for the Enwhe FDP were as follows: Low Capex, Smart Field and Optimized development of the field. The differences between the concepts are the Well counts, gas rate, sand control, degree of smartness and pipeline construction. The alternatives are presented in Table 2.2.

Table 2.2: Enwhe Development Concepts

Development decisions		Development Concepts		
		Low Capex	Smart Field	Optimized Development
		This is focused on a low development cost concept, fewer wells etc. In severely funding constrained environment, this concept is the most attractive	This is focused on minimizing impact on community during production by minimal operational interventions. This concept is best on SD consideration.	This involves development with optimized philosophy (i.e. right amount of wells, complexity, etc).
Subsurface	Well count	4	4 (2-3 reservoirs completed in one well)	6
	Maximum Gas rate/Well	50 – 90 MMscf/d	>100MMscf/d	50 - 90MMscf/d
	Well clustering	2 well clusters	2 well clusters	2 well clusters
Wells	Well Type	Deviated	Deviated	Deviated
	Sand control	As needed	Yes	As needed
	Completion smartness	None	Maximum	Minimum
Surface	Gas metering	Mobile test meter	Multi-phase flow meter	Multi-phase flow meter
	Well fluid gathering system	Individual flowline to RM	Individual flowline to a RM	Individual flowline to a RM
	Manifold location	Enwhe E &W	Enwhe E &W	Enwhe E &W
	Flowline/Bulkline material	CS+SI	CS+SI	CS+SI
	Flowline protection	IPS-HIPPS	Fully Rated	Fully Rated
	Smartness	Current practice	ALoS	ALoS
	Processing	Gbaran CPF	Gbaran CPF	Gbaran CPF
Export	Gas (EGGS-2); Cond. (TNP)	Gas (EGGS-2); Cond. (TNP)	Gas (EGGS-2); Cond. (TNP)	
Remarks		Not recommended	Not recommended	Recommended

The selected concept is Optimized Development which involves gas development with optimized philosophy (i.e. right number of wells), use of one manifold location at Enwhe West, acceptable level of Smartness (ALoS), use of fully rated lines and Multiphase flowmeters for metering and allocation. The Optimized Development concept is selected for the following reasons:

- **Operability and standardization:** The Low Capex concept utilizes mobile test meter for well testing, which significantly increases the complexity of operating the wells requiring operations staff to visit the remote locations each time a well test is carried out. On the other hand, the Optimized Development simplifies the well operation via the use of multiphase flow meters operable and controlled from the Gbaran CPF control room (this is in line with the existing Operating Philosophy for remote testing of wells and remote operations infrastructure).
- **Safety:** Low Capex concept will require frequent well site visits leading to increased personnel exposure. On the other hand, the Optimized development reduces personnel exposure due to utilization of remote capabilities and monitoring from the control room requiring infrequent visit to the well site by operations personnel.
- **Life Cycle Cost:** The use of a mobile test unit in the Low Capex concept entails mobilization of well test vendor each time well test is to be carried out with attendant high mobilization, rental, logistic and operating expenses. It is more likely that the life cycle cost of the low Capex concept will be higher than that of the optimized development concept which utilizes an installed multiphase meter.

2.6.2: Drilling Location alternatives

The drilling location alternatives for the Enwhe FDP is presented in Table 2.3.

Table 2.3: Drilling location alternatives for the Enwhe FDP

Drilling alternatives	Advantages	Disadvantages	Remarks
<p>Drill a total of 6 NAG wells with 11 reservoir targets as part of tranche-1 development.</p> <ul style="list-style-type: none"> • Three (3) wells will be drilled from the existing Enwhe-04 location. • Three (3) wells will be drilled from a new surface location to the west of the field. 	<ul style="list-style-type: none"> • Prompt development of the reservoirs identified as ready-to-go-gas which includes NAG reservoirs and oil rim reservoirs with less than 20ft oil column or fluid uncertainty. • High gas volume in the reservoirs. • Drilling from new location is less complicated. • Risk of delay and not delivering on promises to stakeholders is low. 	<ul style="list-style-type: none"> • Higher overall costs • Additional land take 	<p>Recommended</p>
<p>Drilling from existing Enwhe Wells in the Orashi forest reserve</p>	<p>No new landtake</p>	<ul style="list-style-type: none"> • The location of the current wells is in and around government protected forestry reserves (Orashi Forest reserve). • Due to the age of the wells (49 years), they did not pass the minimum requirement for gas well completions. 	<p>Not recommended</p>

2.6.3: Pipeline Rote Options

The criteria used for selecting the pipeline routes includes but not limited to the following:

1. Environmental and Safety Considerations
 - Impact on sensitive environment
 - Impact on settlements
 - Impact on natural environment
 - Impact on agricultural spread

2. Engineering and Operational Considerations
 - Overall route length
 - Use of existing corridor/land takes
 - Operational & maintenance concerns
 - Interference with existing or proposed facilities

3. Pipeline Constructability
 - River crossings
 - Construction terrain
 - Construction logistics
 - Road crossings

The location map for the pipeline route is presented in Fig 2.1.

Table 2.4: Pipeline route alternatives

Pipeline Route Options	Descriptions	Remarks
Pipeline Route 1	The selected route takes off from the Remote Enwhe Manifold in a North-Easterly direction, avoiding the forestry reserve. The route then runs in a North Westerly direction to Gbaran CPF. The route crosses a river at between and Road Crossings. The communities in proximity to the proposed route include: Okarki, Odua, Egbema, Ikodi	Recommended
Pipeline Route 2	Runs from Enwhe flowstation. It runs Westward along the 16’’ Nun River to Kolocreek trunkline RoW, then across the Upper Orashi Forest reserve and terminates at the Kolocreek flowstation	Not recommended: (Sustainable Development/Biodiversity requirement not to transverse forest reserves)
Pipeline Route 3	Runs Enwhe flowstation towards the South Eastern flange of the area of interest. It runs parallel to the pipeline to Oloibiri flowstation then runs southwards along the EGGS pipeline to Soku GasPlant	Not recommended: Steer from DRB to Process NAG at Gbaran CPF/Long distance to Soku
Pipeline Route 4	Runs from Enwhe Flowstation to Kolocreek flowstation running parallel to Option 1 Pipeline. It runs southwards then west parallel to Option 2 before terminating at the Kolocreek flowstation.	Not recommended: Unavailable ullage at Kolocreek NAG/Oil manifold

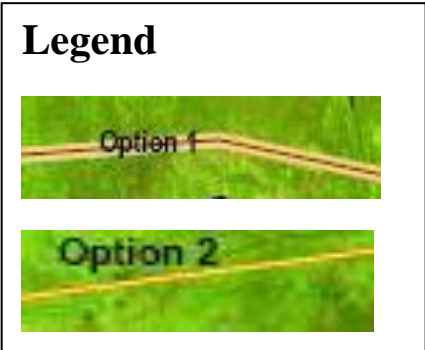


Fig 2.1: Pipeline route selection concepts for the Enwhe FDP

CHAPTER THREE PROJECT/PROCESS DESCRIPTION

3.1: Introduction

The Enwhe field development project is an opportunity to sustain gas supply to NLNG and maximize utilization of Gbaran CPF by developing gas and condensate in the Enwhe field. The details of the scope of work, proposed project activities and Waste Management in the Enwhe field are presented in this chapter.

3.2: Project objectives

The objective of this development is to develop some 0.83 TCF of gas and 15 MMstb Condensate and Oil in Enwhe field aimed at sustaining NLNG gas supply obligation at 2 Bscf/d and address potential demand gap beyond off plateau date of 2021.

3.3: Project location

The Enwhe Field was discovered in 1965 and is located in the south-western corner of SPDC licence OML-22 extending into OML-23 to the east. The field is part of the Gbaran-Ubie Node which is a multi-field oil and gas asset. Enwhe is a greenfield for NAG development located East of the Nun River and East of the Forestry reserve. The terrain is mostly seasonal swamp, typical of the Niger Delta region. The Map showing the Enwhe field is presented in Fig 3.1.

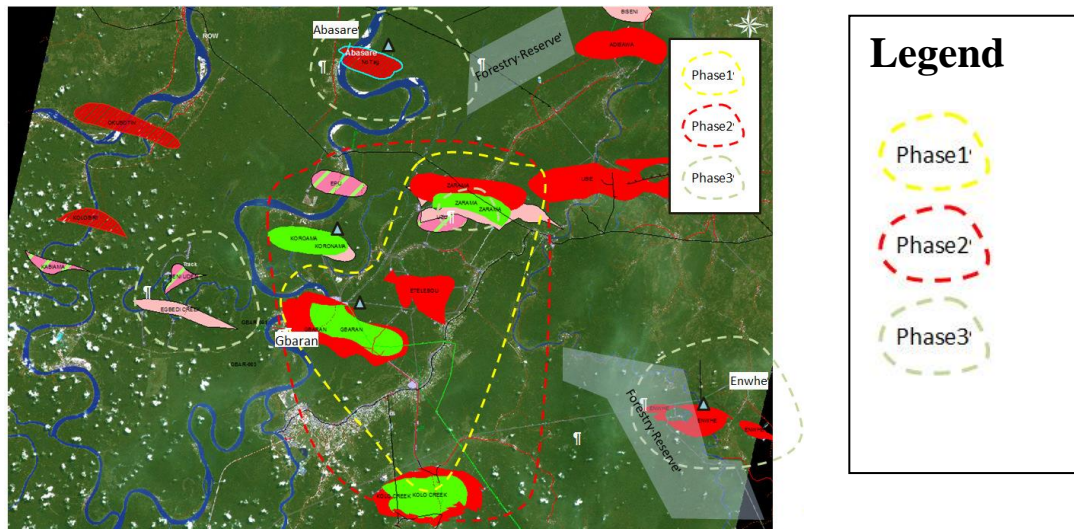


Fig 3.1: Map of the Gbaran field in relation to the Enwhe field

3.4: Proposed Project scope/Overview

The selected concept for Enwhe Opportunity is the Optimized Development termed “Just about

Right Wells and Facilities”. The scope involves mainly drilling, completion of wells and hook-up to the Gbaran CPF.

NAG development Scope:

- Drill and complete 6 wells from 2 wellhead cluster locations.
- Drill appraisal objective from one of the 6 wells.
- Construct 6 x 6” duplex steel flowlines of 0.3 km lengths (total length 1.8 km).
- Install two remote manifold with multi-phase metering and chemical injection skid (Enwhe East and Enwhe West remote manifolds).

Pipeline scope:

The pipelines’ scope for the Enwhe field development scope will include, but will not be limited to:

- Installation of a new 12” x 5.5km CS bulkline from Enwhe East manifold to Enwhe West manifold complete with pig launcher and receiver.
- Installation of new 5.5km long inter-site composite power and fibre optic cable from Enwhe West manifold to Enwhe East manifold.
- Installatio of a new 12” x 36.4km NAG bulkline from the Enwhe NAG Manifold to the Gbaran CPF.
- Installation of new 38km long inter-site composite power and fibre optic cable from Gbaran CPF to Enwhe West manifold.
- Design and installation of pigging facilities on the 12” NAG Bulklines, including the 12-inch Pig Launchers and Receivers, and associated pipework and valves. The Bulkline extends from pig launcher to pig receiver.

Pipeline Dimensions

- 1 no. x 12” 36.4km Enwhe – Gbaran CPF Bulkline
- 1 no. x 12” 5.5km Enwhe East – Enwhe West Bulkline
- 3 no. x 6” 0.3km Enwhe East flowlines
- 3 no. x 6” 0.3km Enwhe West flowlines

Table 3.1: Summary of design parameters for Enwhe Pipelines

Parameter	12" Bulkline	6" Flowlines
Design Life	25 Years	25 years
Design Pressure (barg)	170	202
System Rating	1500#	1500#
Test Pressure (barg)	212.5	252.5
Design Temperature (min/max), °C	0/80	-20/80
Design Factors	0.72 (General route) 0.60 (Facility approach, road/river crossing)	0.60
Pipeline Nominal Diameter	DN300 (12-inch)	DN150 (6-inch)
Pipeline Material	Carbon Steel (ISO 3183 L450)	22% Cr Duplex Stainless Steel (API 5LC 65-2205)
Wall thickness	13.03 mm (0.72 Design Factor) 14.74mm (0.6 Design Factor)	7.9 mm
Corrosion Allowance	4.5 mm	0 mm
Pipeline External Coating		
- Anti-Corrosion	3-layer PE coating	Protective painting (Above ground)
- Weight	Required at River crossings only	None
Cathodic Protection	Impressed Current	Impressed Current
Pigging Requirements	2 nos. Launchers (at Enwhe East NAG manifold and Enwhe West NAG Manifold) 2 nos. Receivers (at Enwhe West NAG Manifold and Gbaran CPF)	Connections for temporary launcher/receiver provided for pre-commissioning activities
	Barrel to ANSI B31.8, Closure to ASME VIII	NA
	Sized for Intelligent Pigs	NA

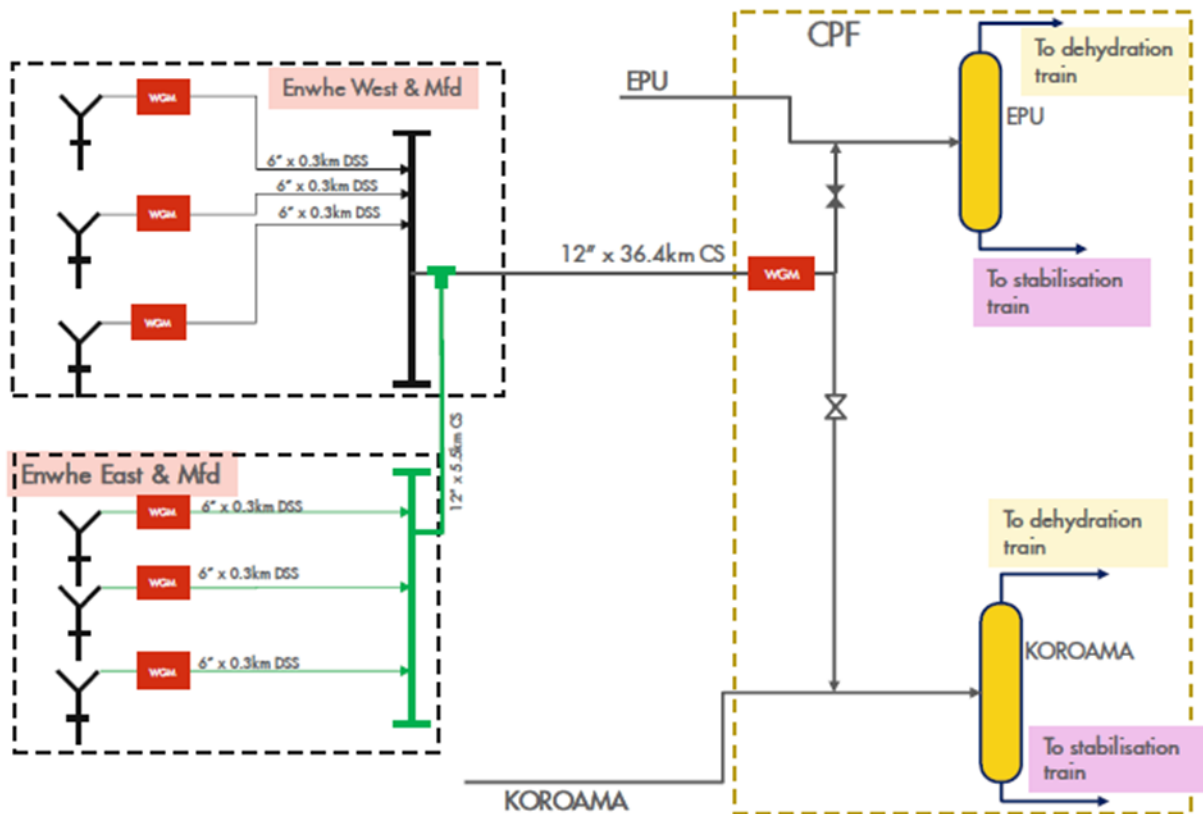


Fig 3.2: Concept schematic for Enwhe field

3.5: Conceptual and detailed design of facilities

3.5.1: Existing infrastructure in the Enwhe field

Enwhe Flowstation

Enwhe flowstation was previously used to process fluids from two wells that were completed as part of a completion campaign in 1974 to develop the D5000 oil reservoir. Enwhe field was closed-in in 1999 following a community disturbance and has not been re-opened. All the surface facilities have been vandalized and no future value beneficial to the proposed Enwhe development. The current plan for Enwhe oil development (tranche 2) is to process in Gbaran CPF.

Existing Wells

There is a historical oil production from the 2 wells completed in the D5000W reservoir, but no non-associated gas production from this field. However, the 2 wells completed are currently closed-in due to community hostility leading to vandalism of the flow station. Current status for the 6 wells drilled is

- * 2 wells suspended,
- * 2 wells abandoned
- * 2 wells closed in.

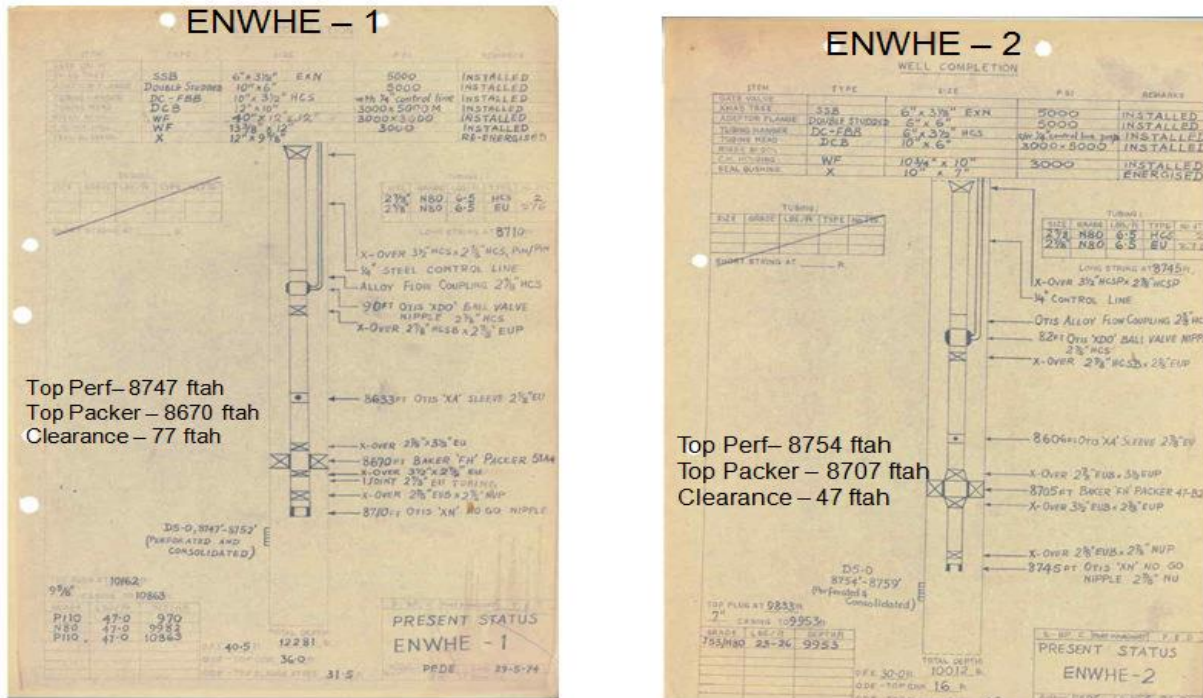


Fig 3.3: Existing Wells in the Enwhe field

3.5.2: Surface Facilities

Well Design considerations

The well conceptual design was made with due considerations to the producing conditions, basic associated risk and design provisions to mitigate the risk. The target reservoirs have relatively good rock properties. Available pore pressure data indicates that the reservoirs of interest are hydrostatic, with no depletion. As due, casing designs for the 6 proposed wells is based on the pore pressures prognosed. High Absolute Open Flow Potentials are expected from the target reservoirs. With the remoteness of the wells, comes the inherent risk of sabotage or accidental collision that may result in ignition/fire on the wellheads. This has been mitigated by the placement of subsurface safety valves.

The reservoirs are relatively unconsolidated sandstone layers, with onset of sand production expected at some stage during the life of the wells. To mitigate possible erosion of tubulars, flowlines and process equipment, each well has been designed to include Sand control mechanism as part of the Lower completions. Compositional analysis of PVT data from analogue fields indicates that there is no threat of H₂S (Hydrogen Sulphide) production from the Enwhe field reservoirs. In addition, CO₂ content ranges from 0.13 to 0.4%. Based on this data and the trend in the Niger Delta, sour corrosion is unlikely. However, the presence of CO₂ evidences the risk of “sweet” corrosion of the tubulars and flowlines. This risk has been reduced to as low as possible through the selection of Corrosion Resistant Alloys (CRA) for completions

tubings and other accessories. Flowline integrity will be safeguarded via the installation of corrosion inhibition systems at surface.

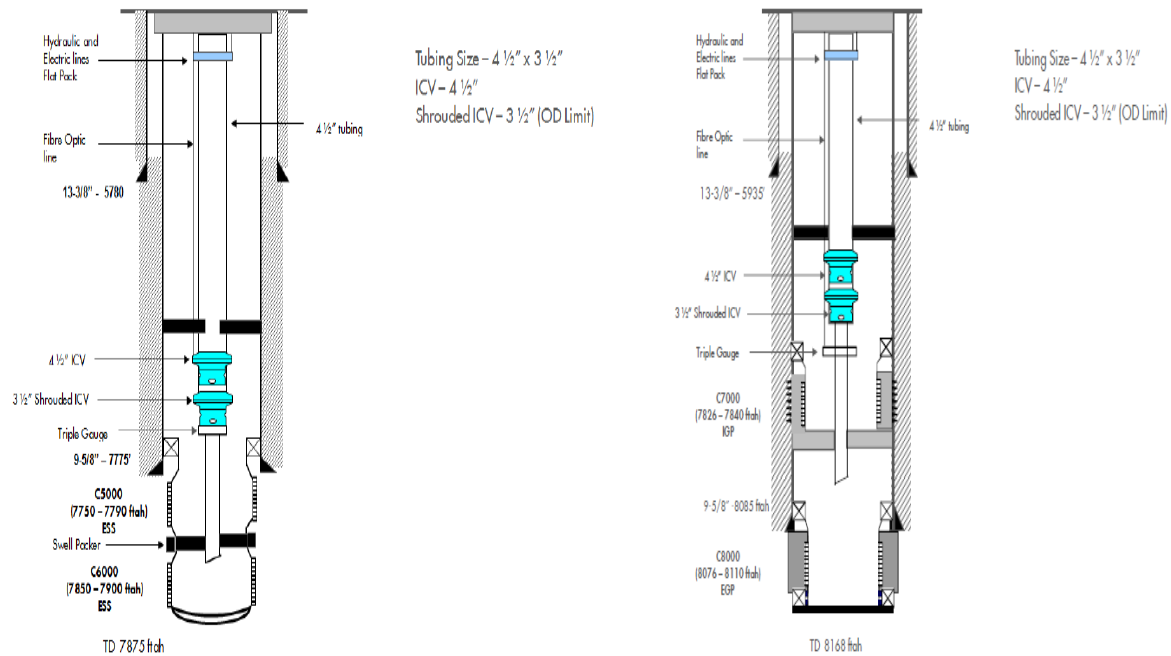


Fig 3.4: Well schematics for the proposed Enwhe NAG Wells

3.5.3: Blow-out Analysis

The risks of loss of containment/blowout and/or ignition and wellhead fire have been reduced to as low as possible. Blowout simulation performed using BLOCOG simulator revealed gas blowout rates of ca 300 MMscf/d, for the proposed wells. In the unlikely event of a blowout, a relief well will be drilled to intersect the blowing well at the top of the reservoir, and kill fluid with density of 1500kg/m³ pumped to kill the blowout well and restore well control. The proposed relief well locations for both clusters are shown in the table below. Opportunity exists for further optimization where other locations become available before commencement of the drilling phase.

SPDC adopts a robust blow-out prevention strategy comprised of 3 hierarchies of control: Primary well control, Secondary well control, and a governing Process Safety Assurance system.

Primary well control is achieved by the use of weighted drilling fluids (mud and completions brine weights) designed to furnish at least 200psi hydrostatic overbalance against reservoir pressures. The nominated drilling rig will be fitted with instrumentation and sensors installed to ensure that the wellbore is filled at all times and that downhole losses (which could lead to loss of hydrostatic overbalance and consequently an influx) are promptly identified and remediated.

Secondary well control involves the installation and use of certified Blow-out Preventers (BOP) and Pressure-control equipment (PCE) to prevent any loss of containment in the event that Primary well control is lost. BOP will be rated for 5,000psi working pressure, which is greater than the maximum anticipated surface pressure for any of the targeted reservoirs in Enwhe field.

SPDC’s drilling operations are governed by Process Safety Assurance guidelines and requirements which aim at ensuring that equipment is fit-for-purpose, and personnel are competent and accountable. These guidelines mandate routine pressure-testing and function-testing of BOP and other safety-related equipment, as well as refresher trainings and certifications of rig-site Supervisors. Comprehensive review of Safety incidents offers valuable root-cause analysis and insights for process improvement.

It is planned to drill the 16-inch top hole with water-based mud (WBM), the 12.25-inch intermediate section with Pseudo-Oil Based (POBM) mud and the 9 5/8 inch reservoir section with solids-free Thixal mud system. Carbon steel casings will be installed and cemented in place across the various hole sections. After cementing and testing production liner, wellbore will be displaced to filtered to 0.47 psi/ft chloride brine. The addition of Oxygen scavenger will mitigate aerobic corrosion and safeguard life-cycle integrity of completions.

The reservoir section will be perforated, and gravel packed.

Table 3.2: Proposed Relief Well location

Well location		Relief Well location			
Location	Wells	Surface location	Distance (m)	Location status	Remark
Enwhe East (Enwhe 004)	F, G, H	Option A: 459340m E; 103075m A	950	Existing	Location preparation required
		Option B: 460292m E; 101794m N	850	Existing	
Enwhe West (New location)	A, C, D	455205m E; 103900m N	500	New	Land acquisition/Location preparation required

Well Clean-Up

Well testing will be carried out to ascertain reservoir parameters (as may be required) to address some reservoir uncertainties, as well as determine skin for assessment of reservoir deliverability. Well clean-up / testing will be performed offline (rig-less) with a Coiled-tubing assembly using industry-standard clean-up and lift techniques. applying underbalanced clean-up technique to lift the well (~500 ft from the sandface) via dedicated test facilities, i.e., if the well can flow by itself. If the well could not sustain flow, coil tubing plus liquid nitrogen will be deployed to enhance lift. The underbalanced clean-up technique will help to remove debris from the perforation tunnel and any mud filter cake and other solids plugging the formation pores. The clean-up recipe will be designed such that a complete filter cake removal is achievable with minimum losses into the formation.

Wells functional requirement

The following are the well functional specifications taken into consideration in the design of Enwhe wells:

- Maximize well deliverability within the constraints of permeability and drawdown.
- Well deliverability of ~ 50 MMscf/d on the average.
- Maximize well value through optimal completion design w.r.t inflow and lift.
- Wells to deplete reserves within their life cycle.

* Well design parameters for Enwhe wells (sample) are provided below:

Table 3.2: Well design parameters for Enwhe wells

Well Data	
Subsurface Architecture (vertical / slanted etc)	Deviated
Production Casing (size, wt, depth)	9-5/8", 47ppf, N80, 8544ftah
Liner (size, wt, depth)	None
Deviation, max DLS	29 degree, 2.3
Any known problem (Wellhead, debris etc)	None
Reservoir Info	
Target (formation name)	C7000W and C8000W.
Depth of top target (TVDSS / AHD)	7533/8108 (C7000W), 7769/8348 (C8000W)
Expected Res Pressure, fluid, H ₂ S, CO ₂ , Cl ⁻ , Solids	3365psia (C7000W) 3478psia (C8000W) 0%, 0.30%, Cl ⁻ not measured
Additional Information	N/A
Additional Well Information	
Max /likely/Minimum life of well	17 years minimum
Expected Flow Rates Gas/Oil/Water (Initial Rates)	50 MMscf/d / 1.8 Mbopd/ 0 WGR
Expected Flowing THP / Temperature	2274psia / 123 F

Completion	
Drilling Fluid	WBM (16" hole); POBM (12-1/4" hole)
Completion Fluid- Formation Damage Acceptance	Calcium Chloride brine
Clean Up Requirements	Yes (Dedicated flare pit to burn cleanup Well effluent)
Safety or Environmental issues	Yes (mitigations in place)
Completion	
Workover frequency and requirements	Work over is not expected in the short and medium term.
Required Well & reservoir surveillance activities. Specify Largest Tool OD for future Surveillance/Lifecycle issues	Completion with dual PDHG for continuous reservoir pressure and temperature measurements to enhance reservoir management and ICVs for optimizing commingle flow. Pressure build up tests to be carried out yearly as statutorily required with installed PDHG
Planned Well Maintenance activities (e.g. scale, treatments)	Preventive Maintenance/FLM: Well Integrity Test(WIT), Subsurface Well Integrity Test(SIT).
Type [single dual other] incl. Initial Well schematic	Single Sting Dual completion
Tubing Size required for inflow performance (P I curves)	4-1/2" 12.6ppf XO 3-1/2" 9.3ppf

Perforating		
Zone Details - Perforation depths:	<u>C7000W</u> 8108 – 8128ftah	<u>C8000W</u> 8348 – 8378ftah
Special measurements e.g. pressure measurement while perf?	Minimum of 200psi overbalance	
Inflow performance and gun performance requirements -Gun type /size charge, shots /ft perf length overbalance / under balance. specify reservoir access requirement and (TCP/WL/CT)	Wireline conveyed, 14spf, Big EHD guns	
Production Logging (Type and OD Debris Tolerance)	Not Applicable	
Well Start-Up Requirements		
Overbalance Required	Minimum of 200psi overbalance	
Artificial lift	None	
Other -e.g. Bean Up Rate	To be captured in Well test/Clean up proposal.	
Production test, duration, data requirements	As per DPR statutory requirements- Six weeks. CGR, WGR, FTHP, FBHP, sand and production rates	
Rig on or off site	Rig off site	
Zones to be tested	C7000W and C8000W	

Design robust wells with a life cycle long enough to optimally deplete reservoir and ensure minimum or no well intervention.

- Design for easy accessibility and operability, such that well intervention activities can easily be carried out when necessary.
- Ensure effective life cycle management that will minimize OPEX.
- No or minimal sand production.
- Ensure protection from sabotage.

- Mitigate for corrosion and minimize impairment.
- Install permanent down-hole gauges for continuous data collection.
- Possible V-Monitors for data transmission to office location.
- Well kill for the NAG wells will be by bull heading.
- Commingling of reservoirs wherever necessary.

Well Path Design

Surface Location and Sub-surface targets selection

Mindful of SPDC’s commitment to sustainable development and environmental policies, minimizing land-take for drilling activities is a key objective. Drilling operations shall be confined to two locations; three wells are to be drilled from an existing well cluster, while the remaining three wells shall be drilled from a new wells site.. Recourse to construction of a new location is warranted as the existing locations in the west fall within a primary forest area and is out of bounds as a drilling location. Due to the cluster requirements, an extension of land needs to be acquired in the existing location to accommodate the slots.

Casing and Completion Design

Casing Design

At 7,455 ftss, the C5000 reservoir is the shallowest hydrocarbon-bearing zone in Enwhe field. The proposed landing depths for the 13-3/8” surface casing strings take this fact into account. All six wells shall have two casing strings: a 13 3/8” surface casing and a 9 5/8” production casing. Casing scheme is based on 4-1/2” or 4 ½” x 3 ½” completion tubing string for the wells. Setting depths are shown in Table 3.3.

Table 3.3: Well Settings Depths

Well	Surface casing	Production casing
	13 3/8” (ftah)	9 5/8” (ftah)
Well A	6297	8178
Well C	6405	8554
Well D	6395	8544
Well F	6278	7981
Well G	5290	8600
Well H	6245	9140

Completion Design

Details of tubing size, material metallurgy and sand-face architecture for the Enwhe wells are provided in the Table below.

Tubing Retrievable Surface-controlled Sub-Surface Safety Valve (TR-SCSSSV) with wireline insert capabilities will be installed in all the wells. Wireline inserts can be run as a contingency in case the tubing retrievable safety valve fails. TR-SCSSSV will be installed at a depth of ±200 ftah and dependent on cratering depth. Proposed well kill philosophy is bull-heading for gas wells. It

is planned to commingle production from reservoirs; thus five of the six proposed wells will have SMART Completions, and will feature downhole equipment and accessories such as Inflow Control Valves (ICVs) and Permanent Downhole Gauges (PDHG)

Table 3.4: Tubing size, Material and Sand face Requirement for the Enwhe Wells

Well Name	To Complete	Tubing	Sand face
Well A	C5000, C6000	4-1/2''x 3-1/2'' 13%CR	SMART, IGP
Well C	C7000, C8000	4-1/2''x 3-1/2'' 13%CR	SMART, Gravelpack
Well D	D1000, D3000	4-1/2''x 3-1/2'' 13%CR	SMART, Gravelpack
Well F	C5000, C6000	4-1/2''x 3-1/2'' 13%CR	SMART, Gravelpack
Well G	D1000	4-1/2'' 13%CR	Gravelpack
Well H	C8000, D3000	4-1/2''x 3-1/2'' 13%CR	SMART, Gravelpack

Mud and Cement Design

Mud Design

It is planned to drill the 16-inch top-hole sections with Water-based mud, while the deeper 12.25 inch hole sections will be drilled with Pseudo-oil-based mud (POBM). Drilling with POBM will provide shale inhibition necessary for wellbore stability and mitigation of drilling-related challenges such as stuck pipe, sloughing shales and excessive rotary torque. The drain hole sections are also planned to be drilled POBM Proposed mud programme for the Enwhe wells is shown in Table 3.5.

Table 3.5: Proposed mud design for the Enwhe Wells

Hole size	Mud type (Weight)	Considerations
16'' Surface hole section	WBM: Bentonite/KCl/Polymer 0.46 – 0.52 psi/ft	<ul style="list-style-type: none"> • Bentonite mud system for good gel properties to effectively transport the high volume of cuttings that will be generated. • Good wall cake building properties for effective control of down hole losses and borehole stability • Break over to KCl/Polymer at +/- 300ft for shale inhibition.
12-1/4'' intermediate hole section	POBM 0.52 – 0.56 psi/ft	<ul style="list-style-type: none"> • POBM for good shale inhibition • Adequate mud weight (density) to provide overbalance for primary well control and borehole stability.

Cement Design

Class G cement slurries will be used to design all the cementing programmes. A dual cement slurry train comprising a lead slurry (~0.624 psi/ft) and 500ft of tail slurry (0.821 psi/ft) will be used for the 13-3/8” surface casing strings. The 13-3/8” casing strings will be cemented to surface. If/where downhole losses are encountered during the cementation of the surface casing, an annulus top-up job will be carried out in compliance with SPDC standard drilling procedures.

For the 9-5/8” production casing strings, it is planned to achieve primary cementation with top of cement at least 500 ft above the shallowest hydrocarbon-bearing interval or 500 ft inside the previous casing in compliance with SPDC and regulatory requirements. Industry-proven procedures will be followed to ensure proper primary cementation, thus eliminating the need for contingency / secondary cementation such as remedial squeezes. For the instances where the cement column will traverse gas-bearing sand intervals, Gasblok additives will be blended into the slurry recipe.

Wellhead Requirement

The wellhead system for the proposed gas wells is made up of the following:

- 13-5/8" x 5000 psi Compact wellhead.
- Casing Hanger and annulus pack-off for the 13 3/8” and 10 3/4” / 9 5/8” casing strings.
- SSMC Tubing hanger.
- Block-type Compact Xmas tree rated for 5,000 psi working pressure, with feed-through port for ScSSV, ICVs and PDHG control lines / fibre-optic cable.

3.5.4: Rig Requirement

The proposed wells shall be drilled with a certified land rig. Some of the key technical specifications and features for the rig include:

- Drawworks capacity of 2,000p or more
- A Top-drive rotary drilling system
- Rig circulation system and pumps rated for 5,000psi and 1200 gallons per min (gpm).
- Surface storage system designed to handle POBM /.
- Tubular handling equipment
- Blow-out Preventers (BOP) rated for 5,000psi service
- Fail-safe instrumentation and sensors for kick detection

3.5.5: Pipeline Route description

Enwhe Remote Manifold to Gbaran CPF Bulkline

The selected route takes off from the Remote Enwhe Manifold (E 454677.79, N 103566.83,) Westerly direction to Gbaran CPF (E 426510.26; 112831.98). The route crosses a river at between (E 441060.72; N 110843.58) and (E 440555.32; N110843.68) and Road Crossings at (E 439005.66, N 110701.67) and (E 436631.185, N 111995.38). The communities in proximity to the proposed route include: Okarki, Odua, Egbema, Ikodi.

Pipeline Location/Key Coordinates

The location and approximate coordinates along the Enwhe Remote Manifold to Gbaran CPF Bulkline are presented in Table 3.6.

Table 3.6: Main locations and approximate coordinates along the Enwhe Remote Manifold to Gbaran CPF Bulkline

EASTING (m)	NORTHING (m)	FEATURE
454677.79	103566.83	Start
456603.64	104832.58	Bend
454596.63	104832.63	Bend
454708.53	109186.21	Bend
444617.84	111089.21	Bend
441060.72	110843.58	River Crossing
440555.32	110808.68	River Crossing
439005.67	110701.67	Road Crossing
437787.15	110617.53	Bend
436993.50	111925.20	Bend
436631.19	111995.38	Road Crossing
436362.38	112030.48	Bend
434242.79	111638.55	Bend
432758.88	112086.51	Bend
428525.06	112635.72	Bend
426925.57	112621.68	Bend
426925.57	112792.19	Bend
426512.00	112792.19	Bend
426510.26	112831.98	End of Line

Flowlines

The flowlines will be routed as follows:

Enwhe East Location Flowlines

The three flowlines will be routed North-west for 5.5 km from Enwhe East Well Location to the Enwhe Remote Manifold, using the already acquired Right of Way. There are two small creek Crossings. The coordinates of the Enwhe East Location Flowlines are presented in Table 3.7

Table 3.7: Coordinates of the Enwhe East Location Flowlines.

EASTING (m)	NORTHING (m)	FEATURE
459524.85	459525.18	Bend
459482.26	102231.36	Bend
459510.89	102210.68	Bend
454702.00	103591.24	Bend
545695.42	103551.44	End

Enwhe West Cluster

The three flowlines are routed west from the Enwhe West Location for 0.1km to the Enwhe Remote Manifold. The coordinates of the Enwhe West Cluster Location Flowlines are presented in Table 3.8.

Table 3.8: Coordinates of the Enwhe West Cluster Location Flowlines.

EASTING (m)	NORTHING (m)	FEATURE
454778.27	103528	Start
454695.31	103546	End

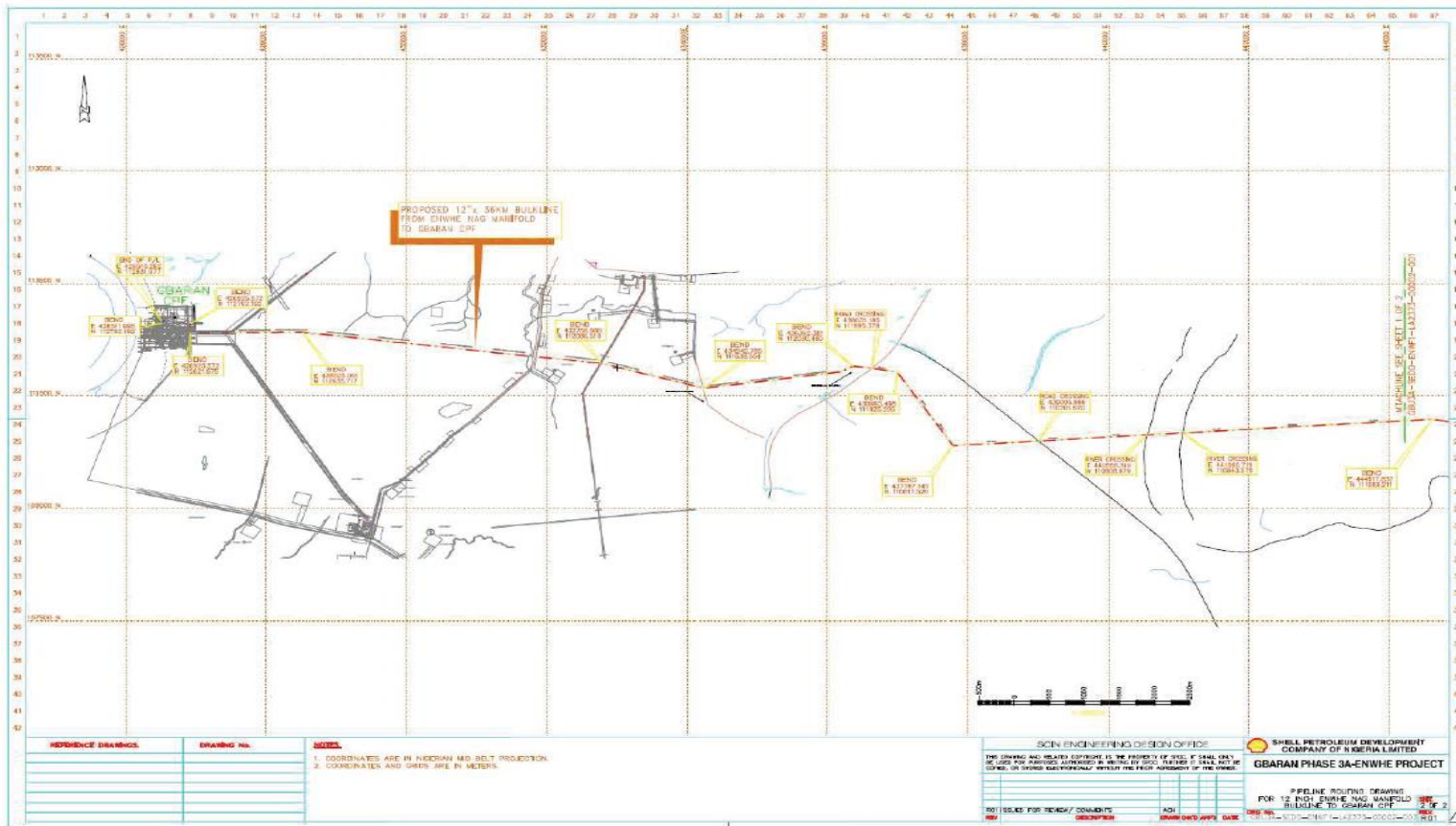


Fig 3.5: Pipeline Route drawing for the 12” line showing Gbaran CPF

3.6: Project activities

3.6.1: Pre-mobilization

Pre-mobilization activities shall include community and other stakeholder engagements and land acquisition. This phase will also include designs and off-site fabrications of modules, pipes etc. During this phase, SPDC shall carry out pre-mobilization inspection of all items/personnel to be mobilized to site. All equipment and personnel mobilized to site shall be certified fit for purpose and approved by SPDC before deployment to site.

3.6.2: Mobilization Phase

This phase will involve:

- Moving construction equipment (dredger, bulldozers, excavators, graders, rollers, pay loaders, asphalt pavers, tippers, trailers, swamp bogey, generators, self loaders, cranes, crew bus, 4WD truck, welding sets, Flushing pumps, Hydro testing unit, Generators, Compressors, Bending Machine, Grit blasting unit, Oxy acetylene torch, Line up clamps, Cold cutter, X-ray units, Thrust boring machine etc) from Contractor's base to site.
- Movement of temporary offices and accommodation to site.
- Set up site office and yard (telecommunication masts, temporary sewage system, messing facilities).
- Movement of personnel from Contractor's base/ SPDC office to site by road.
- Movement of rig to site (this is captured as part of mobilization for the purpose of impact assessment although this comes after well location preparation).

3.6.3: Construction Phase

Well Locations Preparations

Well location preparations shall typically involve vegetation clearing, sand filling, pilling, concrete and asphalt works. The well locations will be surfaced with asphalt to prevent groundwater and soil contamination. In addition, pits will be constructed to capture surface run-off. The pads will be graded so that rainfall on the active portions of the pad will be directed into the pit. Areas for storage of fuel, lubricants, chemicals, solid waste, produced oil, and waste oil will be designated within the well site area to protect the environment, and minimize possible fire and explosion hazards.

Well site construction in a seasonally flooded terrain is typically carried out over a period of 12 months. The number of personnel expected to be working at any point in time during the construction of the access and locations will normally be approximately 70 (seventy) persons. The activities that will be involved in the location preparation in the various fields are described below.

Drilling Workslope and Activities

Logging

This entails deployment of downhole tools on wireline / e-line for the purpose of acquiring Petrophysical data . The interpretation of Petrophysical data thus acquired will prove valuable for sub-surface structural definition, as well as identification and quantification of hydrocarbon accumulations.

Completion

This is the final well construction phase prior to hooking up for production. Activities carried out during well completion include wireline logging, well-bore displacement to brine, reservoir perforation, sand consolidation, Christmas tree installation and production testing. Well engineering operations are concluded when the completed well has been hooked- up to the field manifold.

Pipeline Project Activities

Survey and Staking of Pipeline Routes

Survey shall be carried out to re-establish and clearly mark out boundaries of the permanent ROW and temporary working strip required for construction activities. For a single pipeline route the RoW will be approximately 25 m wide (15 m for the permanent RoW and 10 m for the temporary strip). This temporary strip will be re-vegetated and restored to the owners after construction activities. During FEED keen attention was given to reduction in land take and minimization of environmental footprint. In this regard, where technically feasible multiple pipelines have been routed through common corridors and/or installed in same trench. For example, four flow lines (pipelines) laid separately, along different routes, would require a total of about 60 m way leave, whereas the requirement reduces to 35-40 m way leave, if the pipelines are laid in parallel, along a common corridor. In addition to this, existing RoW have been used where possible instead of acquiring additional land to lay the new pipelines.

Probing for existing facilities

Along existing RoW and at brownfield locations, existing facilities shall be identified and located using drawings and pipe detectors. Manual excavations at appropriate intervals shall confirm exact positions. Inspection of each exposed location shall be carried out and a permanent mark placed on all exposed lines and facilities to indicate which are to be removed and which are to be left in place.

Clearing and grading

The working width shall be cleared of trees and hedges. Ditches shall be flumed by installing pipes and ramped over with subsoil to give a continuous running track through the fields. Topsoil shall then be stripped across the working area and stored at one side. An area of the working width adjacent to the stored topsoil shall be designated as a running track for vehicular movements.

Trenching

A trench, nominally 0.3 – 0.6 m wider than the pipe diameter and deep enough to provide minimum cover, will be excavated to for the pipelines burial. Where the pipeline has to cross existing facility the trench depth will be increased to allow a gap to exist between the two facilities.

Stringing and bending

Stringing and bending involves the handling and positioning of pipes or joints along the ROW on one side of the trench in preparation to welding into a continuous pipeline. Line pipes shall be transported to site from the pipe dumps or lay down areas and laid out on wooden skids along a line parallel to the proposed trench. Gaps are left in the strung pipeline to allow access the working width. Strung pipes shall be provided with caps at both joint ends to keep the joint free from dirt and extraneous materials. Where the pipeline negotiates changes in direction factory manufactured bends will be used or, if the change in direction is less severe, bends will be fabricated at site. As much as possible, deviations will be achieved via elastic bending.

Welding

Before welding, each item shall be visually inspected to ensure that the integrity and general condition of the pipes and fittings have not been compromised during transportation and storage, that they are clean internally and that the ends are correctly prepared for welding. Repairs on any damaged item would be done. Once pipes have been certified fit for use the pipes shall be lined up for welding. Pipes shall be checked, fitted and cleaned to ensure their quality prior to welding. Pipes and fitting shall be lined up for welding with all end caps and similar protections removed immediately before lining up each pipe or fitting. Welding of the joints shall be in accordance with sections 21, 25 and 34 of Shells standard construction specifications. A pipe tally shall be kept showing records of pipe length and wall thickness and number of welds made.

Inspection testing and NDT of welds

Quality assurance and control of the weld shall be achieved by visual inspection and radiographic inspection. 100% radiography of all weld joints shall be employed. All radiography films will be processed and interpreted on site to facilitate quick repairs of defective welds. Records of test results shall be prepared and submitted on a regular basis. Defects shall be repaired or cut out.

Field coating

The weld joint sections and any other sections of the pipeline which are bare or which the coating has been damaged shall be coated to form a continuous protective coating. Heat shrinkable sleeves or repair patches shall be used for repairs of defective field joint coatings taking into account the extent of the portion to be repaired.

Lowering

The welded pipe shall be lowered gently into the ditch without subjecting the line to any stress. The pipes will conform to the ditch and substantially supported by the ditch bottom. The bed underneath the pipe shall be prepared by installation of soft material (medium sand bed) to obtain a soft surround for the installed pipe. The material shall be free of stones, rocks, timber, roots, debris and any other material, which may damage the pipe coating. The sand bed shall have a minimum depth of 150mm. During lowering special care shall be taken to ensure the pipe coatings sustain no damage. Coated pipes shall be handled with rubber-covered broadband slings adequate for the pipe diameter. Slings shall be constructed so that they can be removed from under the pipe without dragging any metal parts against the pipe coating.

Tie-in

After the pipeline sections are lowered into the trench, the sections will be welded together and field joint coated after has been ensure that the integrity and general condition of the sections have not been compromised during lowering. Quality assurance and control of the tie-in weld shall be achieved by visual inspection and radiographic inspection.

Backfilling

Backfilling operation shall follow as closely as possible the lowering and tie-in in operation so that the pipeline and its protective coating will not be damaged. Initial backfilling shall be carried out by installation of soft material (medium sand bed) to obtain a dampened surround for the installed pipe. Initial backfill material shall be free of stones, rocks, timber, roots, debris and any other material, which may damage the pipe coating. The sand bed shall have a minimum depth of 150mm. After the trench has been backfilled, the material shall be tamped down as much as possible and the finish surface left proud of the adjacent ground level to allow for subsequent settlement.

Cathodic Protection

Permanent cathodic protection (CP) facilities shall be installed to protect all Enwhe pipelines. Protection source shall be from deep well ground bed installed at the CPF and remote manifold locations to be determined during design. All CP materials and installations shall conform to the relevant Shell standard construction specifications and DEPs. CP test posts shall be installed at regular intervals along the pipeline route and at where the pipeline crosses other underground steel facilities.

Hydrotesting, Pre-Commissioning and Commissioning

Cleaning, Testing, De-watering and Drying

After all pipeline and manifold sections have been constructed, inspected and tied in, hydro-testing, pre-commissioning and commissioning will be carried out. Hydro-testing and pre-commissioning involves cleaning, gauging, flooding, hydrostatic pressure testing, de-watering and

conditioning of the pipeline systems. It may also involve function checking of valves and other systems. The pipelines will be cleaned using flush water with cleaning pigs. The pipeline shall be deemed clean when no further solid matter or serious discoloration is observed in the receiving pig trap following a pig run and a visual examination of effluent water.

A gauge plate inspection of the pipelines will be run using a plate attached to a suitable pig to transport it through the pipeline. A successful run shall be confirmed when no significant damage caused to the gauging plate is observed. Caliper pig inspection of the pipelines will be run to identify positions of features such as bends, kinks and ovality. Defects observed would be rectified. Baseline intelligent pig inspection (IP) of the pipelines will be carried out to identify any base case anomalies and provide a fingerprint for comparison with subsequent IP inspections

Hydrostatic pressure testing shall be carried out on all pipelines to demonstrate the structural integrity of the constructed pipelines. Water shall be the testing medium. Water used shall be lab tested to prove that it will not damage the pipeline integrity during testing or the environment during disposal. The new line shall be de-watered immediately after pressure testing using compressed air and foam pig. All water recovered from the line shall be tested and treated (where necessary), and sent to Bonny Terminal for further treatment to meet regulatory limits before disposal into Bonny River. When required, as in gas lines, to prevent internal corrosion due to presence of water, the pipeline shall be dried. Drying methods include, nitrogen or air drying with pigs or vacuum drying.

3.6.4: Commissioning and Handover

A pre-commissioning audit of the newly constructed pipelines to verify their conformity with the construction drawings and operability shall be carried out. The contractor shall participate in the pre-commissioning audit, and shall effect any remedial works identified. SPDC personnel shall manage the commissioning operations at the well heads, manifolds and CPF. The contractor shall provide crew support as necessary during the start-up and the introduction of hydrocarbon into the line. Baseline Cathodic Protection (CP) Survey and intelligent pigging shall be carried out prior to handover.

Reinstatement

At the end of site works, contractor shall ensure that the RoWs and work sites are properly cleaned up and reinstated. Although it is manifestly impossible to restore the route traversed by the pipelines to the exact condition in which it was before work started, the general aim should be to make it as nearly as possible. All the debris of construction shall be removed to Shell's approved site. Shell shall issue to the Contractor a Site Restoration Certificate on satisfactory completion of site re-instatement, which is a prerequisite for contract payment.

Risk of Accidents Resulting in Pollution or Hazards

Blow outs and tank leaks are potential causes of accidental spills during drilling activities. A blow out is an uncontrollable discharge of hydrocarbon from the formation. Though the chance of a

blowout is very low, the potential impact on environment is very high. The primary safeguard against a blowout is the pressure exerted by the drilling mud. The mud shall be tested/checked regularly (every 15 minutes on site) to ensure the properties and weights are in order. The secondary control is the equipment referred to as Blow Out Preventer (BOP) with surface safety valves. This equipment shall be used to close in a well at the slightest detection of formation fluid ingress/flow into the well bore (mud system). This equipment shall be tested regularly to ensure proper functionality. Increased land and air logistics, which will result from movement of materials and workers to site, are another potential cause of accidents during drilling construction. Proper logistics management will be put in place as a safeguard.

Based on the nature of the project, activities that will be carried out during project execution, which may impact on the environment include: Location preparation, Vegetation clearing, Sand filling, Piling, Construction of camps, access road, locations and other civil works, Drilling of NAG wells, Laying of flow lines, construction of manifolds and other facilities, etc. These activities will involve human and equipment presence at sites and all waste handling during execution will be in line with all statutory and company guidelines.

Techniques for river crossing

Along the pipeline corridor, there is one (1) major river (Orashi River), one (1) medium river of approximately 100m width, and several minor rivers (width up to 50m). Open cut method shall be considered at minor river crossing. For the major and medium river crossings, HDD, floatation method or push and pull method could be employed, however CONTRACTOR shall assess the areas at the time of construction and propose suitable construction methods for COMPANY's approval. Uncased Thrust boring shall be considered at Major road crossing, and open cut method at minor road crossing.

River and Creek Crossings

At creek/river crossing, the following RoW extent shall apply:

- Medium size creeks/water crossings of between 50m and 200m, the ROW shall be 30m.
- Major water crossings wider than 200m, the RoW shall be 60m.
- On each bank of the crossing, the enlarge RoW width shall extend 30m inland from the bank.

3.6.5: Decommissioning, Abandonment and Restoration

The decommissioning of the project facilities shall involve these main activities:

- Determining the regulatory requirements
- Evolving a community involvement strategy
- Establishing future land use objectives
- Determining objectives of the mothballing plan
- Determining remediation requirements
- Determining reclamation objectives

- Developing a HSE plan

The decommissioning plan for the facilities proposed as part of the Gbaran Phase 3 Project is presented in Table 3.9. This is subject to change in future as technology develops.

Table 3.9: Decommissioning Plan

Facilities	Decommissioning
Wells	Leave potable water wells as agreed with local authorities; isolate production interval to prevent communication between aquifers of different nature or salinity; isolate from the surface; plug and abandon downhole according to applicable guidelines; place surface cement plug below the cellar to allow removal of surface components; backfill to surface.
Flow lines and pipelines.	Purge and flush with water to remove residues; cut above ground lines and sell for scrap; remove or plug and abandon below grade lines.
Redundant buried structures, foundations and cables.	Purge and clean to remove residues; abandon in place or remove completely according to proposed end land use.
Concrete and steel structures including concrete foundations, wellhead cellars, skid foundations and telecom masts, gratings, buildings (including workshops, offices, houses, etc.) and bridges.	Remove steel structures for reuse or recycling; remove wellhead cellar to 1 m below soil surface; remove concrete foundations and slabs down to soil level (unless abandoned in place for future use); break up concrete slabs at ground level into 1 m ² to allow vegetation to regrow through the fissures or remove completely according to proposed end land use; remove buildings or leave in place for reuse; provide access controls for physical structures remaining on-site, that are unsafe or hazardous to humans or animals.
Earthworks such as roads, quarries, asphalt covered areas and walls.	Reach agreement with local authorities & communities for use of usable assets such as roads, remove asphalt for remediation and/or land filling; level mounds and dispose of waste rock; remove and

Facilities	Decommissioning
	recycle or reuse gravel (if clean); decompact subsoils and re-establish vegetation.

All wastes generated in the course of project execution will be handled in line with existing statutory and SPDC Waste Management guidelines.

3.7: Waste and/or By-Products Generated

This section describes the waste and by-products that could be generated during drilling activities.

Drilling Waste

Management of drilling wastes in the Enwhe project will place strategic emphasis on waste minimisation, segregation and recycling. The wastes that will be generated during the drilling operations include:

- Drill cuttings
- Spent drilling mud and completion fluids
- Rig wash (Detergent) water.
- Cementing waste.
- Discarded consumables.
- Domestic waste (solid and sewage).
- Drilling effluents (waste water)

Table 3.9 gives estimated waste volumes from drilling activities per Well.

Table 3.9: Estimated Waste Volume Forecast

Activity	Waste	Volume
Drilling	WBM Cuttings	266.7 m ³ /well
	SBM Cuttings	114.3 m ³ /well
	Plastic drums	<1T
	Metal drums	<1T
	Sewage	11 m ³ /month
	Grey water	50 litres/person/day
	Spent Water Based Mud	101.6 m ³ /well
	Spent Synthetic Based Mud	154.41 m ³ /well
Others	Office waste	1.0 kg/day
	Medical waste	1.5 kg/day
	Kitchen waste (food waste)	10 kg/day

Waste water shall be treated and used for building new mud and also for the rig and equipment washing. Handling, treatment and disposal of drill cuttings will be based on whether they were generated by a water or an oil based drilling fluid system. Drill cuttings generated while drilling with WBM will be channeled into waste pits on site. After a short period of residence in the waste pit, an excavator will be used to scoop the settled-out solids into cutting skips. The cuttings will be washed and used for construction purposes while the waste fluid will be injected into Rumuekpe-004 Cuttings Re-injection well. Conversely, drilled cuttings generated while drilling with POBM will be transported to a Thermal Desorption Unit (TDU) in compliance with FMEnv / DPR directives, while the liquid distillate will be treated and re-conditioned for use..

The Federal Ministry of Environment (FMEnv) and Department of Petroleum Resources (DPR) have approved the use of Rumuekpe-004 for drill cutting re-injection.

Non-Drilling Waste

Discarded consumables which include unused drilling chemicals, packaging for chemicals, rags, scrap metals etc will be properly segregated, and then trucked to SPDC’s recycling facility located at it’s Industrial Area (IA) complex . A strict inventory control of all chemicals in use shall be maintained. All chemicals, lubricating oils and fuels will be stored in containers and safely placed in a sheltered area on the rig. Appropriate Safe Handling of Chemicals (SHOC) cards will be provided for all chemicals handled on the rig

Human Waste

All human wastes shall be treated on site using international standard in-built biological sewage treatment plants. This provides an excellent way of handling all human wastes on board the rig. Under normal circumstances, the total number of personnel on board the rig will not exceed 100.

Waste Generation Forecast

The Project aims at a maximum of 1000 Personnel at the peak of the project. Allowing for occasional visitors, waste generation has been estimated with 1000 personnel working all – time – across all Project sites. Using a weighted average waste generation of 1kg/capital/day, the rate of waste generation is estimated as shown in Table 3.10.

Table 3.10: Estimated Rate of Waste to be Generated

WASTE	RATE OF WASTE GENERATED
Sewage	24lit./day/capita
Food wastes (vegetables/putrescible)	300 kg/day
Glass wastes (burnt bulbs, broken bottles, glass plates and cups)	42 kg/day
Hazardous wastes (e.g. paints, thinners, aerosol cans, Batteries from cars, calculator, radios torches, cameras)	10.2 kg/day
Plastics wastes (cans, polyethylene/ urethane packaging, plates, bags)	150 kg/day

WASTE	RATE OF WASTE GENERATED
Wood and Paper	260 kg/day
Metal Waste	190 kg/day
Textile (e.g. used Hand Gloves non-oil soaked rags)	40 kg/day
Saw Dust	2.2 kg/day

Table 3.11: Waste Identification, handling and disposal

WASTE TYPE / WASTE NAME	Handling			Minimization / Disposal Method /Facility
	Color Code of Bin	Storage	Transportation	
Domestic				
Food/Kitchen Wastes	Green	Keep either in their bins or neatly packaged in a well labelled polythene	Either in their bins or neatly packaged in a well labelled polythene inside a covered truck	Land farming.
Garden Waste	Green	Move to designated storage site in the facility	Transport in covered vehicle with fully completed WCN (Waste Consignment Note)	Move to government approved dumpsite
Garbage	Green	Can be sorted to recover recyclable items	In covered truck with fully completed WCN	Move to government approved dumpsite
Plastic	Brown	Collect & store temporary in recyclable Waste depot.	By land transport to RWD (Recyclable Waste Depot)	Sell to third party for recycling.
Wood	N/A	Store at designated scrap yard	Transport in trucks	Dump at approved dump sites or landfill/Sale to vendors
Office				
Toner cartridge	Navy Blue	Good Housekeeping procedure	Collected with the waste bag closed and transported with appropriate label for recycling	Reuse. Move to WRD – (Waste Recycling Depot), IA, P/H
Paper	Grey	Store under waste shed before moving to RWD	Transport to Recyclable Waste Depot	Recycle; sell to third party for recycling
Industrial				
Glass	Blue	Store in RWD	Transport in closed waste bag with appropriate label to RWD	Recovery & Recycling; Send to glass manufacturing company
Scrap metal	NA	Store in designated areas in the facility	Transport In vehicle/trucks fit for the type of metal to be moved	Re-use, recycle; Move to a WRD (Waste recycling Depot), IA

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WASTE TYPE / WASTE NAME	Handling			Minimization / Disposal Method /Facility
	Color Code of Bin	Storage	Transportation	
Domestic				
Cans and Tins	Black	NA	It shall be collected by waste contractor with the waste bag closed and transported with appropriate label to SPDC dumpsites	Dispose at SPDC approved dumpsite
Computer Scraps & Consumables	N/A	Arrange neatly in a cool dry place	In covered truck with fully completed WCN	Move to the WRD, IA, PH
Oil/Fuel Filters	Blue	Drain oil, cut open to remove diaphragm and crush metal case	In trucks to the scrap metal yard	Send to designated scrap yard where the waste contractor collects them from
Oil Rags	Red Bin	Store in covered plastic bin	In covered truck to disposal site	Incinerate at TDU (Thermal Desorption Unit)
WASTE TYPE / WASTE NAME	Handling			Minimization / Disposal Method /Facility
Industrial Contd.	Color Code of Bin	Storage	Transportation	
Cables	NA	Neatly keep in the Waste depot	In covered truck to disposal site	Re-use; Can be sold to a vendor for re-cycle and reuse
Pigging Waste	Red	Store in Drums and transport to TDU at Bonny	Move to TDU	Burn off in Thermal Desorption Unit (TDU)
Absorbents	NA	Store in storage bins	In Covered Trucks	Burn off in TDU
Spent Oil		Store in dedicated pit	Transport in appropriate drums or tankers.	Collect in dedicated pits and sent to waste oil collector

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WASTE TYPE / WASTE NAME	Handling			Minimization / Disposal Method /Facility
	Color Code of Bin	Storage	Transportation	
Domestic				
Construction Debris	NA	Move neatly to a corner	Mostly done in open vehicles, depending on the size and location for reuse	Reuse in minor road mending
Clinical Waste	Red	Neatly place in black polythene before putting in the red bin.	Transport in sealed bags to SPDC IA incinerator	Incinerated at high temperature in IA.
Fluorescent bulb	Red	Arrange neatly to avoid breaking	In covered truck with fully completed WCN	Recycle; Sell to vendor to recycle mercury.
Sewage	Red	Septic Tanks	The same hauler truck that pumps out the sewage can be used to transport and dispose the sewage	Stock pile in a cool dry place pending the final decision on appropriate disposal option
Chemical drums	Red	Segregate drums and store in compatible groups	In covered trucks	Crush metal drums and sell as scrap. Sell plastic containers to recycling companies.
Spent Batteries	Red	Arrange neatly without breakage in a cool dry place	In covered truck with dully completed WCN	Recycle/Recovery; Move to Recyclable Waste depot (RWD)
Spent Chemical	Red	Store in dedicated pit	Transport in appropriate drums or tankers.	Collect in dedicated pits and sent to waste oil collector

CHAPTER FOUR

DESCRIPTION OF THE EXISTING ENVIRONMENT

4.1: General

The purpose of the baseline data acquisition is to establish, before the execution of the project, the status of the various environmental components that are likely to be affected by the proposed project. A multi-disciplinary approach was adopted for data acquisition and ecological characterization which included climate, air quality and noise, soil, land use/land cover, vegetation, wildlife and biodiversity, aquatic, geology, social and community health status. Data were also generated through literature review of existing environmental studies report in the area, consultations with the stakeholders, detailed field work/study, laboratory and statistical data analysis. Furthermore, a proper Participatory Rural Appraisal/Assessment technique and sampling could not be conducted due to heightened Security challenges especially around Abua/Odual Local Government Area in Rivers State. Also, inaccessibility to some sampling stations especially in the Dry season lead to the short fall in the number of samples approved in the Terms of Reference.

4.2: Literature Review

Some information used for the description of the environment in this report was obtained from the following documents:

- Environmental Management Plan for Gbaran Infill Project, 2016.
- Scientific publications.

4.3: Description of Sampling location

The Enwhe FDP Environmental Impact Assessment Studies involved a two season field data gathering (30th to 12th September, 2016 (Wet season) and 14th to 28th November, 2016 (Dry season)) and covered a spatial boundary of 1km on either side of the proposed Pipeline RoW. Similarly, the study also covered a spatial boundary of 2km radius of the proposed well locations in the Enwhe field. The stratified sampling design protocol was adapted for the study. In stratified sampling, the target population or study area was separated into non-overlapping strata, or subpopulations that are known or thought to be more homogeneous (relative to the environmental sensitivities or contaminants). This allowed for less variation among sampling units in different strata. The strata were chosen on the following bases:

- Vegetation type;
- Surface water bodies and other environmental components and sensitivities;
- Existing wells,
- Human presence and population density;
- Proposed development area (such as well locations and pipelines);
- Professional judgment.

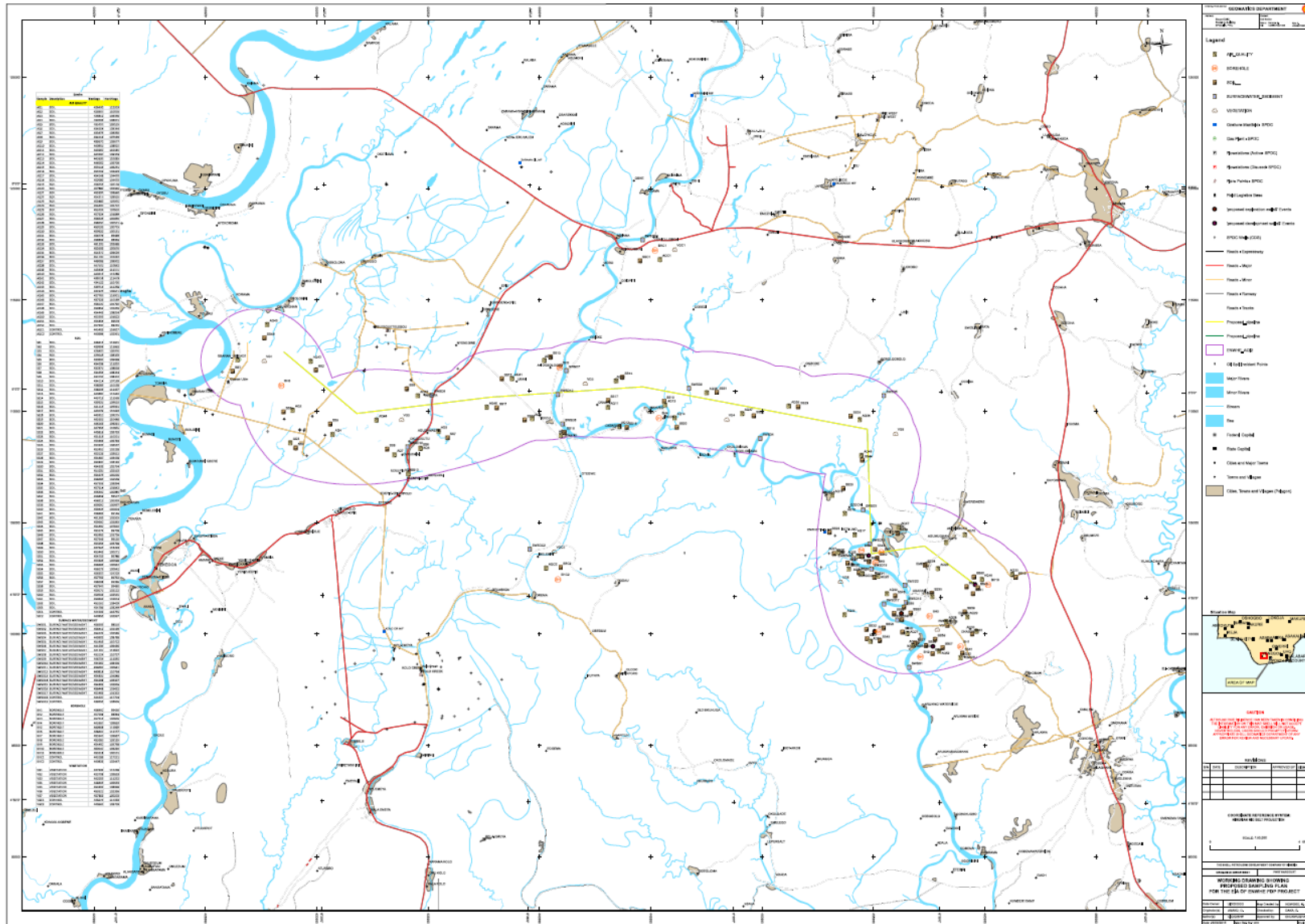


Fig. 4.1: Sampling map for the proposed Enwhe Field Development Plan

The summary of sampling points for various environmental spheres around the Enwhe FDP field is presented in **Table 4.1a**. Sample profiling of all environmental spheres around the proposed RoW, Proposed Wells, Proposed river crossings and control stations are presented in Table 4.1b to Table 4.1e. The details of the coordinates of each environmental component are presented in **Appendix 4.1.2**. All samples were analysed at Earthquest International Limited, Warri, Delta State.

Table 4.1a: Summary of sampling points for various environmental spheres around the Enwhe field

	Environmental components	Proposed number of samples	Actual number of samples taken (Wet)	Actual number of samples taken (Dry)	Remarks
1	Soil	63 + 2 control	63 + 2 control	45+2control	Shortfall due to heightened Security challenges
2	Sediment	17 +2 control	17 +2 control	13+2control	Shortfall due to heightened Security challenges and accessibility
3	Surface water	17 +2 control	17 +2 control	13+2control	Shortfall due to heightened Security challenges and accessibility
4	Ground water	11+2 control	11+2 control	11+2 control	Completed
5	Vegetation/ Wildlife	63 + 2 control	63 + 2 control	45 + 2control	Shortfall due to heightened Security challenges and accessibility
6	Air quality	52+2control	51+2control	41+2 control	Shortfall due to heightened Security challenges
7	Social/Health Profile	21+2control	21+2control	21+2control	Completed

Table 4.1b: Sampling stations around proposed Wells in the Enwhe field

S/N	Soil	Air quality	Surface water/Sediment	Groundwater	Veg/Wildlife
1	SS26	AQ17	SW1	BH1	VG6
2	SS27	AQ20	SW11	BH2	
3	SS28	AQ21	SW13	BH3	
4	SS29	AQ22	SW14	BH7	
5	SS30	AQ23	SW15	BH8	
6	SS31	AQ24	SW16	BH9	
7	SS32	AQ25	SW17	BH10	
8	SS33	AQ26		BH11	
9	SS34	AQ27			

S/N	Soil	Air quality	Surface water/Sediment	Groundwater	Veg/Wildlife
10	SS35	AQ28			
11	SS36	AQ29			
12	SS38	AQ30			
13	SS39	AQ31			
14	SS40	AQ32			
15	SS41	AQ33			
16	SS42	AQ34			
17	SS43	AQ47			
18	SS45	AQ48			
19	SS46	AQ50			
20	SS47	AQ51			
21	SS48	AQ52			
22	SS50				
23	SS51				
24	SS52				
25	SS53				
26	SS54				
27	SS55				
28	SS56				
29	SS57				
30	SS58				
31	SS59				
32	SS60				
33	SS61				
34	SS62				
35	SS63				

Table 4.1c: Sampling stations around proposed Pipeline RoW in the Enwhe field

	Soil	Air quality	Surface water/Sediment	Groundwater	Veg/Wildlife
1	SS1	AQ1	SW3	BH4	VG1
2	SS2	AQ2	SW4	BH5	VG2
3	SS3	AQ3	SW6	BH6	VG3
4	SS4	AQ4	SW7	BH7	VG4
5	SS5	AQ5	SW8	BH8	VG5
6	SS6	AQ6	SW9	BH9	
7	SS7	AQ7	SW10	BH10	
8	SS8	AQ8	SW12		
9	SS9	AQ9	SW13		
10	SS10	AQ10	SW15		
11	SS11	AQ11			
12	SS12	AQ12			
13	SS13	AQ13			
14	SS14	AQ14			
15	SS15	AQ15			
16	SS17	AQ16			
17	SS18	AQ17			

	Soil	Air quality	Surface water/Sediment	Groundwater	Veg/Wildlife
18	SS19	AQ18			
19	SS20	AQ19			
20	SS21	AQ20			
21	SS22	AQ22			
22	SS23	AQ35			
23	SS24	AQ36			
24	SS25	AQ37			
25	SS28	AQ38			
26	SS29	AQ39			
27	SS34	AQ40			
28	SS33	AQ41			
29	SS42	AQ42			
30	SS43	AQ43			
31	SS44	AQ44			
32	SS48	AQ45			
33	SS49	AQ46			
34	SS59	AQ47			
35	SS60	AQ48			
36	SS61	AQ49			
37	SS62				
38	SS63				

Table 4.1d: Sampling stations around proposed Pipeline Crossings

	Orashi Pipeline Crossing at Proposed Wells			Orashi Pipeline Crossing at Akiogbologbo		
	Upstream	Midstream	Downstream	Upstream	Midstream	Downstream
1	SWSD3	SWSD13	SWSD1	SWSD7	SWSD12	SWSD3
2	SWSD4		SWSD2			SWSD4
3	SWSD6		SWSD11			SWSD6
4			SWSD14			
5			SWSD15			
6			SWSD16			
7			SWSD17			

Table 4.1e: Sampling Stations around the Controls

S/N	Air quality	Soil	Groundwater	Surface water	Sediment	Vegetation
1	AQC1	SSC1	GWC1	SWC1	SDC1	VG1
2	AQC2	SSC2	GWC2	SWC2	SDC2	VG2

4.4: Sampling methodology

Table 4.2 gives a summary of the methods/instruments used for sampling various environmental spheres as approved in the Terms of Reference (ToR). The details of the methodology of data acquisition for each of the environmental components are presented in Appendix 2.

Table 4.2: Summary of sample type and method of collection

Environmental Aspect	Method of Samples collection/Field Data Generation
Air Quality and Noise	Aeroqual analyser was used to measure NO ₂ , SO ₂ , NH ₃ , and H ₂ S. Met One Aerosol Mass Monitor was used to capture suspended particulate matter (SPM), Jenway Model Noise meter was used to measure ambient noise level.
Meteorology	Literature Review, Micro-climatic data were captured with Wind meter and Sky master handheld instruments
Vegetation	Transects, key Informant Interviews, Direct Observation and sample collection.
Wildlife	Direct Observation, Key Informant Interviews and indirect count method, observing displayed hunters kill for sales.
Soil Samples/Land use	Dutch hand auger, Core Samplers, Interviews, and Direct Observation, Munsell soil colour chart
Geology/Hydrogeology	Drilling of boreholes and ground water sampling
Surface Water	Water Samplers
Sediment	Sediment Eckman Grab sampler
Hydrobiology/Fisheries/benthos	Collection with, Collection with Plankton Net and sieves, observance of fish landings, interview with fisher folks
Socio-economics/ Health	Interviews, questionnaires, focus group discussions, review of secondary data, direct observations, walk through survey.

4.5: Public Participation/Stakeholder Consultations

Consultation, as defined by the World Bank, involves soliciting ‘peoples views on proposed actions and engaging them in a dialogue’. It is an interactive 2-way flow of information, ideas and opinions between Stakeholders and project Proponents. In consultation, one meets with a person or group of persons to seek their views on a proposed project. The objective of consultation in this type of project includes:

- To inform the Stakeholders of the proposed project
- To encourage participation of the Stakeholders in the EIA process
- To build mutual trust between Stakeholders and the project proponents
- To enable stakeholders’ issues and concerns to be identified, analysed, evaluated and taken into consideration in preparing the EIA report.



Plate 4.1a: Key Informant Interviews (KII) for representatives of communities in the Enwhe Field



Plate 4.1b: Key Informant Interviews (KII) for representatives of communities in the Enwhe Field

Plate 4.1: Key Informant Interviews (KII) for representatives of communities in the Enwhe Field

4.6: Quality Assurance/Quality Control

The following QA/QC was observed in sample collection and *in situ* analysis carried out in the field. Samples were collected in bottles that have been thoroughly washed with detergent (nutrient free) and rinsed thoroughly. Prior to sample collection, each container was rinsed with the water to be sampled before finally collecting the representative sample for laboratory analysis.

- All sampling equipment were properly protected and maintained in accordance with manufacturers' manuals.
- Sampling bottles were adequately labeled with masking tapes and indelible markers to avoid mistaken identity.
- Only analytical reagents (Analar grade) and chemicals were used.
- Automated equipment were calibrated prior to field sampling
- The same stock solutions and standards of H₂SO₄, HNO₃, Na₂S₂SO₃ Winkler's (A and B), and Starch Indicator were used for all the batches of samples to ensure comparability and reliability of results.

4.7: Results

4.7.1: Climate and Meteorology

Regional Climate

The Enwhe Field lies within the humid tropical zone with its characteristic heavy rains. The wet season is from April to October and dry season from November to March. However, rains can start as early as March and end in November. The months with the highest rainfall are June, July and September. Climatologically, four seasons are discernible for the region: the early rainy season (March-July), little dry season (also called August break), late rainy season (September-November) and dry season (December-February). Annual rainfall for the study area is around 2600 mm. Over 70% of this total occurs between June and October. During the dry season, the Northeast Trade Winds may sweep through the region. This wind is generally dust-laden which also largely restricts visibility particularly between December and February. Clouds during this period are absent so temperature is relatively high during the day but low at night. As the overhead sun moves into the Northern hemisphere in March, the influence of the *Harmattan* retreats and the maritime wind begins to dominate the area once again for the rest of the seasons.

The average annual air temperature in the study area ranges from 26 to 28 °C. Diurnal ranges vary from season to season, and may be up to 10°C in the dry season especially during December-January (*Harmattan* period) and only 4°C in July-September (rainfall peak). Diurnal temperature peaks 1-3 hours after noon, and drops to minimum in the early hours of dawn.

Relative Humidity is constantly high reaching over 90% during the rainy season particularly at dawn and minimum by late afternoon in the dry season (70%). The incidence of fog in the region is common, especially in February-March during the transition from dry to rainy season but it is easily dispersed by the first radiation of the sun.

Table 4.3a: Average Long-term Climatic Data for Rivers State (2002-2011)

S/No	Month	Air Temp (°C)	Rainfall (mm)	Cloud Cover (oktas)	Pressure (mbar)	R/H (%)	Wind Speed (m/s)	Wind Dir.
1	January	33.3	15.4	6.9	1006.3	74	2.94	NE
2	February	34.2	76	6.8	1005.7	77	2.6	E
3	March	33.6	93.1	6.9	1005.5	80	3.5	SW
4	April	32.5	141.2	6.9	1005.7	83	3.3	SW
5	May	32	244.2	6.9	1007.1	86	4.2	SW
6	June	30.4	307.4	7	1008.7	88	4.2	SW
7	July	29.2	354.5	7	1009.6	90	4.9	SW
8	August	29.5	320.3	7	1009.2	90	4.8	SW
9	September	29.3	365.6	7	1008.8	90	4.2	SW
10	October	30.8	241.2	6.9	1007.5	89	3.6	SW
11	November	32.1	74	6.8	1006.6	85	2.6	NE
12	December	33.2	18.6	6.8	1006.5	78	2.8	NE

Source: Nigerian Meteorological Agency,

Table 4.3b: Monthly rainfall (mm) for the Bayelsa State area (1991 – 2010)

Month	Maximum Rainfall (mm)	Minimum Rainfall (mm)	Minimum Temperature (°C)	Maximum temperature (°C)	Relative humidity (%)	Wind speed (m/s)
January	85.2	0.0	22.8	32.2		
February	153.5	2.3	23.8	33.6		
March	306.1	5.2	24.6	33.3		
April	345.2	46.5	24.4	33.1		
May	430.5	113.2	23.8	31.9		
June	462.6	114.8	23.2	30.5		
July	742.4	162.0	22.7	28.6		
August	682.3	49.4	22.9	27.3		
September	722.9	91.3	22.6	29.3		
October	647.5	59.7	23.1	30.9		
November	312.8	0.0	23.9	32.4		
December	140.3	0.0	22.8	32.1		

Source: Nigerian Meteorological Agency,

Microclimatic Conditions

A summary of Meteorological measurements in the study area is presented in Table 4.3c. Detailed results are presented in Appendix 4.6.1.

Table 4.3c: Statistical summary (Mean±SD) of onsite microclimatic data in the Enwhe field in the Wet and Dry season

Parameters	Wet season		Dry Season	
	Study Area	Control(x±SD)	Study Area(x±SD)	Control(x±SD)
Air Temp. (°C)	29.79±1.99	32.45±1.06	30.81±2.81	29.65±0.07
Relative Humidity (%)	71.90±8.25	70.3±0.85	60.68±6.61	64.7±10.47
Wind Speed (m/s)	0.94±0.85	0.55±0.07	1.02±0.90	1.5±0.71
Wind direction	SW**** SE** W* E* NE*	SW****	SW****	
Air Turbulence	Calm	Calm	Calm	Calm
Atm. Pressure (hpa)	1011.7±1.56	1011±1.41	1007±1.63	1007.5±0.70

Source: Field Survey 2016

Ambient Temperature

As expected for a tropical region, high atmospheric temperatures were recorded around the area and at the control locations. The mean average temperature was 29.79 °C in the wet season compared to 30.81°C in the dry season. At the control location, mean temperature was 32.45°C in the wet season and 29.65°C in the dry season. Spatial variations in relation to control were not significant. The atmospheric temperatures are normal for the region.

Relative Humidity

Relative humidity expresses the degree of wetness or dryness of the atmosphere. Relatively high humidity was measured at the locations with a mean of 71.9% in the wet season and 60.68% in the dry season. At the control, the dry season mean was 64.7% while the wet season recorded 70.3%. These values are normal for the study area.

Wind Speed

Wind velocities were observed to be very light (<3.6 m/s are considered very light winds) at all the sites monitored. The mean wind speed was 0.94 m/s in the wet season and 1.02 m/s in the dry season. The relatively higher dry season values are related to the sampling period; November is actually a transition period between wet and dry season in the area and are usually characterized with relative stronger winds. A similar trend was observed at the control locations in both seasons.

Wind Direction

The winds were dominated by South westerlies in both seasons. During the rainy season winds from the SE, S, E and NE were also observed in some instances but the winds were generally calm. This is normal in Coastal regions of Nigeria.

Air Pressure

Average sea-level pressure is 1013.25 hpa. Atmospheric pressure was generally within normal range of sea level pressure with levels being slightly lower in the dry season (1007 hpa) compared to wet season (1011 hpa).

4.7.2 Air Quality and Noise Level Studies

The summary of results of air pollution studies for the area are presented in Tables 4.4a for physicochemical parameters and 4.4b for heavy metals, while detailed results are presented in Appendices 4.6.2a - d.

Table 4.4a: Statistical summary (Mean±SD) of air quality variables (gaseous pollutants) in the Enwhe field in the Wet and Dry season

Parameters	Wet season			Dry season			DPR limit	FMEnv limit
	PW	PRoW	CTR	PW	PRoW	CTR		
SPM($\mu\text{g}/\text{m}^3$)	0.9±0.5	0.83±0.58	1.85±0.92	1.93±1.7	2.03±1.43	1.81±1.7	60-90	250
NO ₂ (ppm)	<0.001±0	<0.001±0	<0.001±0	<0.001±0	<0.001±0	<0.001±0	0.08	0.04-0.06
SO ₂ (ppm)	<0.001±0	<0.001±0	<0.001±0	<0.001±0	<0.001±0	<0.001±0	0.04-0.06	0.01
H ₂ S(ppm)	<0.001±0	<0.001±0	<0.001±0	<0.001±0	<0.001±0	<0.001±0		
NH ₃ (ppm)	<0.001±0	<0.001±0	<0.001±0	<0.001±0	<0.001±0	<0.001±0		
CO(ppm)	<0.001±0	<0.001±0	<0.001±0	0.01±0.02	0.01±0.01	<0.001±0	10	10
VOC(ppm)	<0.001±0	<0.001±0	<0.001±0	<0.001±0	<0.001±0	<0.001±0		
O ₃ (ppm)	<0.001±0	<0.001±0	<0.001±0	<0.001±0	<0.001±0	<0.001±0		
Noise(dB(A))	51.77±6.03	52.65±10.66	51±6.65	50.34±3.02	54.99±7.84	55.3±2.4	85	90

PW=Proposed Wells; PRoW=Pipeline RoW; CTR =Control

Source: Field Survey 2016

Table 4.4b: Summary of results of heavy metal concentrations in the ambient air in both climatic regimes

Parameters	Wet season			Dry season		
	PW	PRoW	CTR	PW	PRoW	CTR
Fe (mg/kg)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cu (mg/kg)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Zn (mg/kg)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Hg (mg/kg)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Pb (mg/kg)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cd (mg/kg)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Ni (mg/kg)	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
<i>PW=Proposed Wells; PRoW=Pipeline RoW; CTR =Control</i>						

Source: Field Survey, 2016

, Sulphur dioxide (SO₂), Hydrogen sulphide (N₂S), Ammonia (NH₃),. Similarly, heavy metals were not detected in all atmospheric samples at study locations and control.

Green House Gases

A green house gas is any gas that has the property of absorbing infrared radiation (net heatenergy) emitted from Earth's surface and reradiating it back to Earth's surface, thus contributing to the greenhouse effect. Carbon dioxide, methane, and water vapour are the most important greenhouse gases. These gases contribute directly to climate change owing to their positive radiative forcing effect. Water vapor is the most abundant greenhouse gas, but most scientists believe that water vapor produced directly by human activity contributes very little to the amount of water vapor in the atmosphere. The primary greenhouse gases in Earth's atmosphere are water vapor, carbon dioxide, methane, nitrous oxide and ozone. At current emission rates temperatures could increase by 2 °C, which the United Nations' IPCC designated as the upper limit to avoid "dangerous" levels, by 2036. Nitrogen dioxide (NO₂), Volatile organic compounds (VOC) and Ozone (O₃) were undetected during the study. Other indirect greenhouse gases such as SO₂ was not detected while

Carbon monoxide (CO) was undetected during the wet season but very low levels (Mean of 0.01 ppm) were measured in the dry season around the Proposed Wells (PW) and Pipeline RoW (PRoW). These values are below the permissible limit of 10 ppm recommended by the Federal Ministry of Environment. Low levels of CO can arise from biological processes and reaction of hydroxyl radicals with methane derived from decomposition of living matter and the growth and decomposition of plants containing chlorophyll (WHO). The most important anthropogenic source is from incomplete combustion of carbon-containing materials and

industrial processes (WHO, 1987). The proposed project may increase the levels of CO in the area from vehicular activities and combustion of carbon containing compounds.

Suspended Particulate Matter:

Particulate Matter (SPM) ranged from mean value of 0.83 $\mu\text{g}/\text{m}^3$ around the proposed wells area to 0.90 $\mu\text{g}/\text{m}^3$ along the pipeline RoW compared to control of 1.85 $\mu\text{g}/\text{m}^3$ during the wet season and from 1.93 to 2.03 $\mu\text{g}/\text{m}^3$ compared to control of 1.81 $\mu\text{g}/\text{m}^3$ during the dry season. The lower values during the rainy season is related to atmospheric wash-out of particulates by rainfall. All values measured are low when compared with Nigerian Ambient Air Quality Standards of 250 $\mu\text{g}/\text{m}^3$ and other International standards. The baseline air quality of the study area is therefore unpolluted. Suspended particulate matter (SPM) can be found in ambient air in the form of dust, smoke, or aerosols. SPM may be of anthropogenic and/or natural origin. Direct sources of SPM include burning of fossil fuels (coal, oil, wood) for power generation, heating and transportation; construction and industrial activities; as well as soil erosion (windblown dust), forest fires, volcanic eruptions, and pollen. SPM can occur as a secondary aerosol resulting from atmospheric transformation of gaseous pollutants emitted from combustion sources (e.g. power plants and automobiles) or natural sources such as forests. Particles can also result from condensation of volatile elements and species in the atmosphere to form very small particles or absorb on the surface of already formed, finely divided particles. The proposed project has the potential to contribute to particulates in the atmosphere.

Table 4.4c: Nigerian Ambient Air Quality Standard

Pollutants	Time of Average	Limit
Particulates	Daily average of daily values 1 hour	250 $\mu\text{g}/\text{m}^3$ 600 $\mu\text{g}/\text{m}^3$
Sulphur oxides (Sulphur dioxide)	Daily average of hourly values 1 hour	0.01ppm (26 $\mu\text{g}/\text{m}^3$) 0.1ppm (260 $\mu\text{g}/\text{m}^3$)
Non-methane Hydrocarbon	Daily average of 3-hourly values	160 $\mu\text{g}/\text{m}^3$
Carbon monoxide	Daily average of hourly values 8-hourly average	10ppm (11.4 $\mu\text{g}/\text{m}^3$) 20ppm (22.8 $\mu\text{g}/\text{m}^3$)
Nitrogen oxides (Nitrogen dioxide)	Daily average of hourly values (range)	0.04ppm – 0.06ppm (75.0 $\mu\text{g}/\text{m}^3$ - 113 $\mu\text{g}/\text{m}^3$)
Photochemical oxidant	Hourly values	0.06ppm

Noise level

The ambient noise levels varied from 51.77-52.75 dB(A) during the wet season compared to control of 51 dB(A) while dry season levels varied from 50.34-54.99 dB(A) compared to control of 55.3 dB (A) with no significant spatial variations. All measured noise levels were within 90 dB(A) which is the Permissible limit for Nigeria in an 8 hour working period (FMENV. 1991).

Noise levels increased in the dry season due to increased human activities. The proposed project has the potential to increase noise levels due to increased vehicular, machinery and human activities during and after the construction of the project. All parameters of air quality and noise within the study area are within acceptable limits both at the study locations and control.

4.7.3 Surface Water Quality

The summary of results of physicochemical measurements in surface water are presented in Tables 4.5a and 4.5b for the wet and dry seasons respectively. Detailed results are presented in Appendix 4.6.3a & b. All results are presented in relation to sampling strategy to cover the Proposed Wells (PW), Pipeline Right of Way (PRoW) and Pipeline River Crossings (near proposed wells and near Ogiogbologbo community).

pH

Average pH values varied between 6.70 at Proposed Wells area (PW) to 7.5 at the Mid-stream of the Pipeline River Crossings (MSPW and MSAGIO) compared to control of 6.95 during the wet season and from 6.71 at Up-stream of river crossing near Ogiogbologbo (USAGIO) to 7.15 at Down-stream of river crossing near Proposed wells (DSPW) compared to control of 7.04. All pH values were either slightly acidic or slightly basic and well within the normal pH values of 6.5-8.5 for unpolluted surface water and those previously reported for rivers of the Niger Delta (RPI/NNPC, 1985). The pH of most natural waters is between 6.0 and 8.5, although lower values can occur in dilute waters high in organic content, and higher values in eutrophic waters, groundwater brines and salt lakes (Chapman, 1992).

Redox Potential (Eh):

Redox potential ranged from a mean of 4.63 mV at USPW and DSAGIO to 45.9 mV at MSPW compared to control of 0.65 mV during the wet season and from -29.5 mV at MSPW to 30.64 mV at PW compared to 25.95 mV at control during the dry season. Redox potentials were higher during the dry season and with less spatial variation compared to the wet season. The Eh of natural waters are usually reported to vary from - 500 mV to + 700 mV. Surface waters and ground waters containing dissolved oxygen are usually characterized by a range of Eh values between + 100 mV and + 500 mV. In contrast, some mineral waters such as those connected with oil deposits show markedly lower levels and may even reach the limit value of - 500 mV (Chapman, 1992). The redox potentials are relatively low.

Turbidity, Total Suspended Solids (TSS) and Colour:

Turbidity, colour and suspended solids are related parameters and usually vary in response to the similar factors. Average levels of Turbidity ranged from 49.6 NTU at MSAGIO to 112.4 NTU at MSPW compared to control of 15045±8421 NTU during the wet season and from 18.48 NTU at PW to 43 NTU at MSAGIO compared to control of 46.2 NTU during the dry season. Dry season values were significantly lower than wet season concentrations. The range of turbidity in

natural waters is 1 to 2000 NTU (Mills, 2013). High turbidity levels are common in Niger Delta rivers (Akpan *et al.*, 2003). High wet season values are due to surface run-off of silt from river catchment into the surface waters. The proposed project has the potential to increase the turbidity of associated surface waters.

Mean levels of TSS ranged from 34 mg/l at MSAGIO to 78 mg/l at USAGIO compared to 26.5 mg/l at control and from 23 mg/l at MSPW to 52 mg/l at MSAGIO compared to 46 mg/l at the control during the dry season. Levels during the wet season were also significantly higher and more varied than those of the dry season which may be attributed to rain-related input of silt and other materials via surface run-off. Values of TSS ranging from 1.2 to 397 mg/l have been previously reported for the Niger Delta Rivers (RPI/NNPC, 1985). Present levels are normal for rivers of the Niger Delta. The proposed project has the potential to increase suspended solids in associated surface waters.

Mean water colour varied from 15.43 units at DSPW to 29 units at USAGIO compared to control of 22.5 units during the wet season and from 7.8 units at DSPW to 26 units at USAGIO compared to control of 18 units. Dry season values were generally lower than wet season concentrations. The seasonal variation is related to rain-related inputs of materials including humic substances from the catchment via surface run-off. The values are normal for forested aquatic systems of southern Nigeria (Akpan, *et al.*, 2003).

Electrical conductivity (EC), Total Dissolved Solids (TDS) and Salinity:

Conductivity, total dissolved solids and salinity are related parameters used as measured of salt concentration. Mean value of electrical conductivity ranged from 15.81 $\mu\text{S}/\text{cm}$ at PW to 39.3 $\mu\text{S}/\text{cm}$ at USAGIO compared to control of 38.8 $\mu\text{S}/\text{cm}$ during the wet season and from 15.6 $\mu\text{S}/\text{cm}$ at DSPW to 32.31 $\mu\text{S}/\text{cm}$ along PRow compared to control 38.4 $\mu\text{S}/\text{cm}$ at the control during the dry season. There were no significant differences between levels in the wet and dry season but all levels were those characteristic of freshwaters and within limits of previous report for Niger Delta Rivers (10 – 42,100 $\mu\text{S}/\text{cm}$; RPI/NNPC, 1985). Natural fresh waters are reported to vary between 50 and 1500 $\mu\text{S}/\text{cm}$ (ILMB, BC, 1998, Chapman, 1992).

Total Dissolved Solids ranged from a mean of 8.04 mg/l at PW to 19.7 mg/l at USAGIO compared to control of 19.4 mg/l during the wet season and from 7.3 mg/l at MSPW to 9.35 mg/l at DSAGIO compared to 19.4 mg/l at the control. Spatial variations were observed but with no clear trend. The values were generally characteristic of freshwaters.

Salinity (as Chloride) ranged from 1.56 mg/l at MSPW to 8.69 mg/l at USAGIO compared to 51.44 mg/l at the control during the wet season and from 3.07 mg/l at MSAGIO to 8.12 mg/l at PRow compared to control of 8.63 mg/l at control. Values at study locations were generally higher during dry than wet season but the control showed the opposite trend. All values were

characteristic of freshwaters. RPI/NNPC (1985) reported a range of 3.0 – 18,648 mg/l for the Niger Delta..

Table 4.5a: Summary results of Physicochemical measurements in Surface water around Enwhe Field during the wet season

Parameters	PW	PRoW	USPW	MSPW	DSPW	USAGIO	MSAGIO	DSAGIO	CTR	RPI/NNPC, 1985
pH	6.7±0.84	7.15±0.4	6.75±0.35	7.5±0	6.68±0.82	6.9±0	7.5±0	6.75±0.35	6.95±0.35	3.1-8.6
Redox Potential, mV	21.17±54.77	-12.53±32.3	4.63±11.4	45.9±0	8.54±58.2	11.1±0	-46.3±0	4.63±11.4	0.65±20.01	
Electrical Conductivity, µS/cm	15.81±3.92	27.96±12.8	18.43±6.31	19.3±0	32.02±44.58	39.3±0	21±0	18.43±6.31	38.7±0	0.01-42.1
Turbidity, NTU	54.49±35.68	89.05±70.34	86.87±72.2	112.4±0	61.34±50.29	81.6±0	49.6±0	86.87±72.2	15045±8421	
TSS, mg/L	41±28.68	67.3±48.44	61±48.14	89±0	41.14±28.96	78±0	34±0	61±48.14	26.5±3.54	1.2-397.0
TDS, mg/L	8.04±2.05	14.05±6.39	9.27±3.11	9.7±0	16.14±22.24	19.7±0	10.8±0	9.27±3.11	19.4±0	0.002-35.35
THC, mg/L	0.64±0.36	<0.1	<0.1	0.72±0	0.6±0.5	<0.1	<0.1	<0.1	<0.1	
COD, mg/L	8.06±1.19	10.03±2.89	11.07±2.54	7.36±0	8.19±1.15	16.36±0	8.56±0	11.07±2.54	7.43±1.59	1.95-2,460.0
DO, mg/L	7.2±1.37	6.33±1.61	6.8±0.36	8.1±0	7.01±1.31	6.9±0	7.1±0	6.8±0.36	4.85±1.91	2.0-9.0
BOD ₅ mg/L	2.83±0.71	2.77±0.8	3.43±0.59	2.3±0	2.89±0.67	3.1±0	2.5±0	3.43±0.59	1.95±1.06	
Salinity as Cl, mg/L	1.86±1.15	3.42±2.64	1.97±1.11	1.56±0	7.56±15	8.69±0	2.9±0	1.97±1.11	51.44±65.5	3.0-18,648.0
Odour	ND	ND	ND	ND	ND	ND	ND	ND	ND	
Nitrite, mg/L	0.04±0.03	0.04±0.02	0.03±0.01	0.05±0	0.04±0.03	0.02±0	0.02±0	0.03±0.01	0.02±0	
Colour(Pt-Co)	16.86±8.73	20±6.04	16.33±4.04	28±0	15.43±7.3	29±0	21±0	16.33±4.04	22.5±3.54	
Alkalinity mg/L	29.71±3.74	32±2.3	31.5±2.5	31.5±0	29.71±3.74	31.5±0	31.5±0	31.5±2.5	35.25±5.3	
Oil & Grease mg/L	1.08±0.65	<0.01±0	<0.01±0	1.3±0	0.98±0.88	<0.01±0	<0.01±0	<0.01±0	<0.01±0	
Nitrate mg/L	0.16±0.05	0.35±0.69	0.85±1.26	0.11±0	0.19±0.09	0.19±0	0.16±0	0.85±1.26	0.13±0.01	BDL-5.44
Phenols mg/L	<0.05±0	<0.05±0	<0.05±0	<0.05±0	<0.05±0	<0.05±0	<0.05±0	<0.05±0	<0.05±0	
Sulphate mg/L	2.15±0.85	2.82±1.89	1.98±0.41	3.18±0	2.53±1.64	2.35±0	2.19±0	1.98±0.41	4.69±2.36	
Ammonia mg/L	1.05±0.18	1.5±0.74	1.43±0.59	1.33±0	1.08±0.24	1.07±0	1.07±0	1.43±0.59	0.79±0.11	
Phosphate mg/L	0.16±0.11	0.32±0.23	0.12±0.01	0.36±0	0.16±0.12	0.24±0	0.16±0	0.12±0.01	0.11±0.01	0.049-0.584
reactive silica mg/L	1.15±0.34	1.16±0.31	0.78±0	1.47±0	1.03±0.35	1.08±0	1.42±0	0.78±0	1.24±0.3	

PW=Proposed Wells; PRoW=Pipeline RoW; USPW = Upstream of Proposed Wells; MSPW =Midstream of Proposed Wells; DSPW = Downstream of Proposed Wells; USAGIO = Upstream of Agiogbologbo; MSAGIO = Midstream of Agiogbologbo; DSAGIO = Downstream of Agiogbologbo; CTR = Control, BDL=Below Detection Limit; Source: Enwhe Field Development EIA Field Data September, 2016 (Wet season)

Table 4.5b: Summary results of Physicochemical measurements in Surface water around Enwhe Field during the dry season

Parameters	PW	PRoW	USPW	MSPW	DSPW	USAGIO	MSAGIO	DSAGIO	CTR	RPI/NNPC, 1985)
pH	7.13±0.1	6.93±0.25	6.95±0.35	7.02±0	7.15±0.09	6.71±0	6.9±0	6.95±0.35	7.04±0.51	3.1-8.6
Redox Potential mV	-30.64±1.52	-24.31±8.07	-24.3±11.03	-29.5±0	-30.86±1.39	-15.2±0	-28.1±0	-24.3±11.03	-25.95±10.68	
Electrical Conductivity µS/cm	15.7±0.71	32.31±26.72	18.65±0.35	14.6±0	18.8±6.33	15.6±0	16±0	18.65±0.35	38.4±19.66	0.01-42.1
Turbidity NTU	18.48±1.82	22.83±11.48	27±9.9	19±0	15.86±5.85	19.3±0	43±0	27±9.9	46.2±12.45	
TSS mg/L	23.6±3.97	28.43±13.56	29±18.38	23±0	20.4±8.47	28±0	52±0	29±18.38	46±2.83	1.2-397.0
TDS mg/L	7.86±0.35	16.36±13.69	9.35±0.21	7.3±0	9.44±3.22	7.8±0	8±0	9.35±0.21	19.4±10.04	0.002-35.35
THC mg/L	<0.1±0	<0.1±0	<0.1±0	<0.1±0	<0.1±0	<0.1±0	<0.1±0	<0.1±0	<0.1±0	
COD mg/L	7.05±1.01	7.85±1.66	8.75±0.65	5.36±0	7.45±0.35	6.13±0	10.08±0	8.75±0.65	7.63±0.83	1.95-2,460.0
DO mg/L	6±0.58	5.96±0.67	5.95±0.07	5.8±0	6.2±0.66	5.5±0	6.4±0	5.95±0.07	5.9±0.57	2.0-9.0
BOD ₅ mg/L	2.24±0.5	2.24±0.53	2.2±0.42	2.9±0	2.18±0.41	2.9±0	2±0	2.2±0.42	2.6±0.28	
Salinity as Cl mg/L	4.8±0.75	8.12±5.04	6.01±1.32	5.08±0	5.02±0.98	5.08±0	3.97±0	6.01±1.32	8.63±5.87	3.0-8,648
Nitrite mg/L	0.01±0.01	0.01±0	<0.001±0	<0.001±0	0.01±0	<0.001±0	<0.001±0	<0.001±0	<0.001±0	
Colour(Pt-Co)	8.2±2.77	13.43±6.11	11.5±3.54	12±0	7.8±2.17	26±0	15±0	11.5±3.54	18±1.41	
Alkalinity mg/L	42±6.16	41.43±2.99	40±2.83	46±0	40.8±5.76	40±0	42±0	40±2.83	44±0	
Oil & Grease mg/L	<0.01±0	<0.01±0	<0.01±0	<0.01±0	<0.01±0	<0.01±0	<0.01±0	<0.01±0	<0.01±0	
Nitrate mg/L	0.02±0.01	0.01±0.01	0.004±0	0.02±0	0.02±0.01	0.004±0	0.01±0	0.004±0	0.01±0	BDL-5.44
Phenols mg/L	<0.05±0	<0.05±0	<0.05±0	<0.05±0	<0.05±0	<0.05±0	<0.05±0	<0.05±0	<0.05±0	
Sulphate mg/L	0.96±0.66	0.87±0.34	0.97±0.17	0.49±0	1.22±0.69	0.49±0	0.87±0	0.97±0.17	1.66±1.18	
Ammonia mg/L	0.23±0.07	0.19±0.03	0.19±0.01	0.12±0	0.22±0.09	0.2±0	0.18±0	0.19±0.01	0.16±0.02	
Phosphate mg/L	0.04±0.01	0.03±0.01	0.02±0	0.04±0	0.03±0.01	0.03±0	0.02±0	0.02±0	0.03±0.02	0.049-0.584
reactive silica mg/L	0.68±0.29	0.52±0.2	0.45±0.16	0.59±0	0.7±0.28	0.85±0	0.62±0	0.45±0.16	0.73±0.3	

PW=Proposed Wells; PRoW=Pipeline RoW; USPW = Upstream of Proposed Wells; MSPW =Midstream of Proposed Wells; DSPW = Downstream of Proposed Wells; USAGIO = Upstream of Agiobologbo; MSAGIO = Midstream of Agiobologbo; DSAGIO = Downstream of Agiobologbo; CTR = Control, BDL=Below Detection Limit; Source: Enwhe Field Development EIA Field Data November, 2016 (Dry Season)

Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD₅) and Chemical Oxygen Demand (COD)

Dissolved oxygen ranged from a mean value of 6.33 mg/l at PRoW to 7.2 mg/l at PW compared to control of 7.43 mg/l during the wet season and from 5.5 mg/l at USAGIO to 6.4 mg/l at MSAGIO compared to 5.9 mg/l at control during the dry season. Most water quality criteria for protection of aquatic life recommends DO values of 5 mg/l (Alken Murray Corp., 2006) and above but below 110% saturation (RAMP, 2000). The amount of dissolved oxygen is considered poor if the concentration is less than 2 mg/l, a condition referred to as hypoxia (Chapman, 1992, Rabalais *et al.* 2002). RPI/NNPC (1985) reported DO levels between 2 and 9 mg/l for waters of southern Nigeria. The measured levels are considered normal for unpolluted environments.

Biochemical Oxygen Demand ranged from mean of 2.3 mg/l at MSPW to 3.43 mg/l at USPW and DSAGIO compared to control of 1.95 mg/l at control and from 2 mg/l at MSAGIO to 2,24 mg/l at PW and PRoW compared to control of 2.6 mg/l during the dry season. There were wide spatial and seasonal variations in BOD levels with no clear trend. Unpolluted waters typically have BOD of 2 mg/l or less, whereas water in contact with wastewater may have values up to 10 to 15 mg/l (Chapman and Kimstach, 1992). The observed BOD values are normal for unpolluted surface waters.

Chemical Oxygen Demand varied from mean value of 7.36 mg/l at MSPW to 16.36 mg/l at USAGIO compared to control of 7.43 mg/l during the wet season and from 5.36 mg/l at MSPW to 10.08 mg/l at MSAGIO compared to control of 7.63 mg/l at the control during the wet season. Wet season values were relatively higher than dry season values but all levels were low and characteristic of unpolluted waters. A range of 1.95 to 2,460 mg/l was reported by RPI/NNPC (1985) for the Niger Delta.

Nutrients-Ammonium, Nitrate and Phosphate:

Ammonium ranged from 1.05 mg/l at PW to 1.5 mg/l at PRoW compared to 0.79 mg/l at the control during the wet season and from 0.12 mg/l at MSPW to 0.23 mg/l at PW compared to control of 0.16 mg/l during the dry season. The un-ionized form of ammonia (NH₃) should not exceed 0.05 mg/l in order to protect aquatic organisms (Francis-Floyd *et al.*, 2015). Considering the ambient pH (~7) and temperatures during the study, the concentration of un-ionized ammonia would not exceed 20% of total ammonia and therefore not of any toxicological concern..

Nitrate ranged from 0.11 mg/l at MSPW to 0.85 mg/l at USPW and DSAGIO compared to control of 0,13 mg/l during the wet season and from 0.004 mg/l at USAGIO, DSAGIO and USPW to 0.02 mg/l at PW compared to control of 0.01 mg/l during the dry season. Wet season values were significantly higher than dry season levels indicating the effect of rainfall and surface run-off on concentrations which is also responsible for the higher spatial variability in the wet season. Nitrate levels were generally low and within the range of BDL to 5.44 mg/l reported previously for the

Niger Delta (RPI/NNPC,1985). In non-polluted waters, the world average of nitrates is 0.30 mg/l (Mills, 2013). Concentrations in excess of 20 mg/l nitrate usually indicate pollution by human or animal waste, or fertilizer runoff (Chapman and Kimstach, 1992).

Mean Phosphate levels ranged from 0.12 mg/l at DSAGIO to 0.36 mg/l at MSPW compared to control of 0.13 mg/l during the wet season and from 0.02 mg/l at DSAGIO, MSAGIO and USPW to 0.04 mg/l at PW, and MSPW compared to control of 0.03 mg/l in the dry season. Wet season values were significantly higher than dry season values indicating the impact of rainfall input and run-off from catchment. Spatial variations were higher in the wet season compared to dry season indicating the importance of local inputs from surface run-off. Most natural waters have phosphate levels ranging from 0.01 to 0.05 mg/l (Mills, 2013). RPI/NNPC (1985) gave a range of 0.049 to 0.584 mg/l for phosphate in rivers of southern Nigeria. Present values are therefore normal for the study area.

Mean Reactive silica concentration ranged from 0.78 mg/l at DSAGIO and USPW to 1.47 mg/l at MSPW compared to control of 1.24 mg/l and from 0.45 mg/l at USPW and DSAGIO to 0.85 mg/l at USAGIO compared to 0,73 mg/l at the control. Wet season values were higher than dry season values and spatial variability was also higher in the wet season showing the effect of surface run-off inputs. Silicate is mainly of importance as nutrient in the growth of diatoms which utilize it for the formation of their shell matter. Natural concentrations can range from a few parts per million (ppm) in surface water to more than 100 ppm in groundwater. For instance, the soluble silica concentration of Mississippi River-water averages 4.0-7.5 ppm (Bien, *et al.*, 1958). The observed concentrations in the study area are low and within normal levels in unpolluted waters.

Alkalinity

Alkalinity represents the sum of components (mainly bicarbonate, carbonate, and hydroxide) in the water which buffers it against changes in pH. Alkalinity ranged from a mean of 29.71 mg/l at PW and DSPW to 32 mg/l at PRow compared to 35.25 mg/l at control during the wet season and from 40 mg/l at USAGIO to 46 mg/l at MSPW compared to 44 mg/l at the control during the dry season. Spatial variation was not significant but dry season values were significantly higher than wet season values indicating the impact of rain dilution of carbonates and bicarbonates. The alkalinity values are normal for freshwaters. To offset acids produced by nitrifying bacteria, alkalinity above 75 mg/L is recommended. The acceptable range for most finfish is 20-200 mg/l (ppm).

Sulphate

Sulphate ranged from a mean of 1.98 mg/l at USPW and DSAGIO to 3.18 mg/l at MSPW compared to 4.69 mg/l at the control during the wet season and from 0.49 mg/l at MSPW and USAGIO to 1.22 mg/l at DSPW compared to 1.66 mg/l at control during the dry season. Concentrations were significantly higher during the wet season indicating the input of sulphates

from biogenic sources via surface run-off into the waters. Observed sulphate levels are low and characteristic of freshwater environments.

Total Hydrocarbons (THC) and Oil & Grease (O&G)

Levels of THC and O&G were generally below the limits of detection particularly during the dry season. Locations with measureable concentrations during the wet season were PW, MSPW and DSPW. Average THC ranged from 0.6 mg/l at DSPW to 0.72 mg/l at MSPW compared to undetectable levels in the control. Similarly, O&G ranged from a mean of 0.98 mg/l at DSPW to 1.3 mg/l at MSPW compared to undetectable levels at the control. The surface waters were therefore not contaminated with petroleum; the minor levels being associated with inputs from run-off during the wet season.

Cations and Heavy metals

The summary of results of metals measurements in surface water are presented in Tables 4.5c and 4.5d for the wet and dry seasons respectively. Detailed results are presented in Appendix 4.6.3c & d.

Sodium, Potassium, Calcium and Magnesium:

Mean concentration of sodium ranged from 1.12 mg/l at USPW and DSAGIO to 4.68 mg/l at USAGIO compared to control of 5.47 mg/l at control during the wet season and from 1.22 mg/l at MSAGIO to 1.6 mg/l at USPW and DSAGIO compared to control of 1.72 mg/l at the control during dry season. Levels were significantly higher during the wet than dry season. Similarly, spatial variations were higher during the wet season. Sodium levels were generally low and characteristic of freshwater environments. The proposed project has the potential to increase the sodium levels of associated surface waters through waste and effluent discharges and interference with drainage patterns.

Potassium ranged from a mean of 0.6 mg/l at MSAGIO to 2.9 mg/l at USAGIO compared to control of 2.32 mg/l at control during the wet season and from 0.2 mg/l at USAGIO to 1.0 mg/l at MSPW compared to control of 0.54 mg/l at control during the dry season. Potassium levels were relatively higher during the wet season than dry season but no significant spatial differences in relation to the control. The proposed project has the potential to increase the potassium levels of associated surface waters through waste and effluent discharges and interference with drainage patterns.

Calcium ranged from a mean of 0.32 mg/l at MSAGIO to 0.70 mg/l at MSPW compared to control of 0.33 mg/l at the control during the wet season and from 0.23 mg/l at USAGIO to 0.34 mg/l at USPW and DSAGIO compared to control of 0.23 mg/l during the dry season. Rainy season values were higher than those of the dry season but variation between stations and control was not significant.

Magnesium ranged from a mean of 0.24 mg/l at MSAGIO to 0.52 mg/l at MSPW compared to control of 0.26 mg/l at the control during wet season and from 0.12 mg/l at USPW and DSAGIO compared to control of 0.2 mg/l at the control during dry season. Values were significantly higher during the wet season than dry season but variation with control was not significant.

Higher levels of cations during the wet season compared to dry season is due to run-off of terrestrial materials into the surface waters during rains. All cation levels were low and characteristic of freshwater environments.

Heavy metals

Apart from Zinc, Iron and Manganese, all other heavy metals were below analytical detection limits in the study area. Iron ranged from a mean value of 0.52 mg/l at MSPW to 2.31 mg/l at USAGIO compared to control of 0.53 mg/l during the wet season and from 0.67 mg/l at USAGIO to 0.93 mg/l at MSPW compared to 0.86 mg/l at the control during the dry season. Wet season values were significantly higher than dry season values. During the wet season, levels at control were lower than those of the study location but there was no spatial difference during the dry season. The observed levels are within the BDL to 4.75 mg/l reported by RPI/NNPC (1985).

Manganese ranged from a mean of 0.08 mg/l at PW and MSAGIO to 0.11 mg/l at USPW and DSAGIO compared to 0.06 mg/l at the control and from 0.04 mg/l to 0.06 mg/l at MSPW compared to control of 0.04 mg/l. Wet season values were higher than the dry season concentrations but spatial variation were not significant.

Zinc varied from a mean concentration of 0.11 mg/l at USAGIO to 0.63 mg/l at DSPW compared to control of 0.27 mg/l and from 0.29 mg/l to 0.32 mg/l compared to control of 0.29 mg/l during the dry season. Wet season values were higher than the dry season values but spatial variations were not significant. Zinc levels were within the range reported by RPI/NNPC (1985) of BDL - 0.770 mg/l for the Niger Delta. In general, while the levels of cations and heavy metals are low and within background values, there is a strong tendency for inputs from catchment during rains.

Table 4.5c: Summary results of metals measurements in Surface water around Enwhe Field during the wet season

Parameters	PW	PRoW	USPW	MSPW	DSPW	USAGIO	MSAGIO	DSAGIO	CTR	RPI/NNPC, 1985
Na mg/L	1.69±0.68	3.56±2.54	1.12±0.03	2.01±0	4.6±7.87	4.68±0	3.07±0	1.12±0.03	5.47±0.3	
K mg/L	0.84±0.16	1.03±0.7	0.91±0.04	0.93±0	1.55±1.93	2.9±0	0.6±0	0.91±0.04	2.32±0.73	
Ca mg/L	0.39±0.2	0.47±0.19	0.44±0.18	0.7±0	0.37±0.17	0.42±0	0.32±0	0.44±0.18	0.33±0.03	
Mg mg/L	0.31±0.12	0.32±0.1	0.33±0.08	0.52±0	0.28±0.07	0.28±0	0.24±0	0.33±0.08	0.26±0.04	
Mn mg/L	0.08±0.04	0.09±0.03	0.11±0.03	0.05±0	0.1±0.05	0.11±0	0.08±0	0.11±0.03	0.06±0.01	
Fe mg/L	1.1±1.02	1.52±0.83	1.48±0.9	0.52±0	2.06±2.49	2.31±0	1.28±0	1.48±0.9	0.53±0.14	BDL - 4.75
Cd mg/L	<0.001±0	0.01±0	<0.001±0	<0.001±0	<0.001±0	<0.001±0	<0.001±0	<0.001±0	<0.001±0	BDL - 0.092
Cr mg/L	<0.005±0	0±0	<0.005±0	<0.005±0	<0.005±0	<0.005±0	<0.005±0	<0.005±0	<0.005±0	BDL - 0.971
Ni mg/L	<0.005±0	0±0	<0.005±0	<0.005±0	<0.005±0	<0.005±0	<0.005±0	<0.005±0	<0.005±0	BDL-1.379
V mg/L	<0.005±0	0±0	<0.005±0	<0.005±0	<0.005±0	<0.005±0	<0.005±0	<0.005±0	<0.005±0	BDL -1.563
Pb mg/L	0.04±0.02	0.02±0.01	0.01±0.01	0.01±0	0.04±0.02	0.02±0	0.01±0	0.01±0.01	0.03±0.01	BDL - 1.354
Zn mg/L	0.35±0.15	0.42±0.24	0.36±0.17	0.29±0	0.63±0.72	0.11±0	0.51±0	0.36±0.17	0.27±0.05	BDL -0.770
Hg mg/L	<0.02±0	<0.02±0	<0.02±0	<0.02±0	<0.02±0	<0.02±0	<0.02±0	<0.02±0	<0.02±0	

PW=Proposed Wells; PRoW=Pipeline RoW; USPW = Upstream of Proposed Wells; MSPW =Midstream of Proposed Wells; DSPW = Downstream of Proposed Wells; USAGIO = Upstream of Agioglobogbo; MSAGIO = Midstream of Agioglobogbo; DSAGIO = Downstream of Agioglobogbo; CTR = Control

Source: Enwhe Field Development EIA Field Data September, 2016 (Wet season)

Table 4.5d: Summary results of metals measurements in Surface water around Enwhe Field during the dry season

Parameters	PW	PRoW	USPW	MSPW	DSPW	USAGIO	MSAGIO	DSAGIO	CTR	RPI/NNPC, 1985
Na mg/L	1.46±0.17	1.31±0.23	1.6±0.21	1.34±0	1.52±0.17	1.27±0	1.22±0	1.6±0.21	1.72±0.01	
K mg/L	0.62±0.42	0.61±0.33	0.64±0.33	1±0	0.47±0.39	0.2±0	0.95±0	0.64±0.33	0.54±0.48	
Ca mg/L	0.33±0.04	0.31±0.05	0.34±0.04	0.32±0	0.33±0.04	0.23±0	0.27±0	0.34±0.04	0.23±0.01	
Mg mg/L	0.15±0.05	0.15±0.04	0.12±0	0.13±0	0.14±0.05	0.14±0	0.13±0	0.12±0	0.2±0.13	
Mn mg/L	0.05±0.03	0.04±0.02	0.04±0.01	0.06±0	0.05±0.03	0.04±0	0.08±0	0.04±0.01	0.04±0.01	
Fe mg/L	0.77±0.21	0.78±0.16	0.8±0.18	0.93±0	0.69±0.21	0.67±0	0.8±0	0.8±0.18	0.86±0.09	BDL - 4.75
Cd mg/L	0.01±0	<0.001±0	<0.001±0	<0.001±0	<0.001±0	<0.001±0	<0.001±0	<0.001±0	<0.001±0	BDL - 0.092
Cr mg/L	<0.005±0	<0.005±0	<0.005±0	<0.005±0	<0.005±0	<0.005±0	<0.005±0	<0.005±0	<0.005±0	BDL - 0.971
Ni mg/L	<0.005±0	<0.005±0	<0.005±0	<0.005±0	<0.005±0	<0.005±0	<0.005±0	<0.005±0	<0.005±0	BDL-1.379
V mg/L	<0.005±0	<0.005±0	<0.005±0	<0.005±0	<0.005±0	<0.005±0	<0.005±0	<0.005±0	<0.005±0	BDL -1.563
Pb mg/L	0.03±0.01	0.02±0.01	0.01±0	0.04±0	0.03±0.02	0.03±0	0.03±0	0.01±0	0.04±0	BDL – 1.354
Zn mg/L	0.32±0.03	0.29±0.01	0.29±0	0.31±0	0.32±0.03	0.3±0	0.31±0	0.29±0	0.29±0	BDL -0.770
Hg mg/L	<0.02±0	<0.02±0	<0.02±0	<0.02±0	<0.02±0	<0.02±0	<0.02±0	<0.02±0	<0.02±0	

PW=Proposed Wells; PRoW=Pipeline RoW; USPW = Upstream of Proposed Wells; MSPW =Midstream of Proposed Wells; DSPW = Downstream of Proposed Wells; USAGIO = Upstream of Agiobologbo; MSAGIO = Midstream of Agiobologbo; DSAGIO = Downstream of Agiobologbo; CTR = Control

Source: Enwhe Field Development EIA Field Data November, 2016 (Dry season)

Microbiology

The summary of results of Microbiological measurements in surface water are presented in Tables 4.5e and 4.5f for the wet and dry seasons respectively. Detailed results are presented in Appendix 4.6.3e and f.

Coliform Bacteria:

Total coliforms ranged from a mean of 4 MPN/100ml at MSAGIO to 10 MPN/100 ml at MSAGIO compared to control of 10 MPN/100 ml at the control during the wet season and from 2 MPN/100 ml at MSAGIO and MSPW to 6.6 MPN/100 ml at DSPW compared to control of 4 MPN/100 ml during the dry season. Values were significantly higher during the wet season showing the impact of surface run-off inputs. Most drinking water quality standards recommend that drinking water should be devoid of all Coliform bacteria. Although coliform bacteria are not harmful in most cases, their presence in water supply it is an indicator of the potential occurrence of other harmful and disease causing bacteria and such waters are considered as being presenting a potential health hazard and classified as unsafe for human consumption.

Total Heterotrophic Bacteria (THB):

THB ranged from mean value of 0.5×10^3 cfu/ml at MSAGIO to 0.91×10^3 cfu/ml at MSPW compared to 0.54×10^3 cfu/ml at the control during the wet season and from 0.29×10^3 cfu/ml at MSAGIO to 0.39×10^3 cfu/ml at DSPW compared to control of 0.23×10^3 cfu/ml at the control during the dry season. Values were significantly higher during the wet season compared to the dry season but there was no significant difference compared to control.

Hydrocarbon Utilizing Bacteria (HUB):

HUB ranged from a mean of 0.2×10^2 cfu/ml at MSAGIO to 0.44×10^2 cfu/ml at PRow compared to control of 0.22×10^2 cfu/ml during the wet season and from 0.1×10^2 cfu/ml at MSPW to 0.31×10^2 cfu/ml at MSAGIO compared with control of 0.13×10^2 cfu/ml during the dry season. Values were significantly higher during the wet season than dry season but spatial variation compared to control was not significant. The percentage of HUB to THB is usually used as indication of petroleum hydrocarbon pollution. Levels below 10% is regarded as indicator of unpolluted environment (Atlas, 1982). The levels of HUB are generally very low (10 orders of magnitude lower) relative to THB signifying no oil pollution in the environment.

Total Heterotrophic Fungi (THF) and Hydrocarbon Utilizing Fungi (HUF)

Mean levels of THF and HUF were generally low and non-detectable in several samples particularly around the pipeline crossings near Agiogbogbo.

Table 4.5e: Summary results of microbiological measurements in Surface water around Enwhe Field during the wet season

Parameters	Units	PW	PRoW	USPW	MSPW	DSPW	USAGIO	MSAGIO	DSAGIO	CTR
Coliform Count	MPN/100 ml	6.86±3.39	9±3.71	8.67±3.79	7±0	7.43±3.74	10±0	4±0	8.67±3.79	10±1.41
HUB	cfu/ml X 10 ²	0.35±0.16	0.44±0.2	0.31±0.06	0.34±0	0.33±0.17	0.36±0	0.2±0	0.31±0.06	0.22±0.16
HUF	cfu/ml X 10 ²	0.05±0.02	0.04±0.01	0±0	0±0	0.07±0.05	0±0	0±0	0±0	0±0
THB	cfu/ml X 10 ³	0.59±0.24	0.69±0.21	0.85±0.11	0.91±0	0.5±0.22	0.51±0	0.5±0	0.85±0.11	0.54±0.08
THF	cfu/ml X 10 ²	0.07±0.02	0.12±0.1	0.04±0	0.05±0	0.06±0.03	0±0	0.03±0	0.04±0	0.05±0
<i>PW=Proposed Wells; PRoW=Pipeline RoW; USPW = Upstream of Proposed Wells; MSPW =Midstream of Proposed Wells; DSPW = Downstream of Proposed Wells; USAGIO = Upstream of Agiobologbo; MSAGIO = Midstream of Agiobologbo; DSAGIO = Downstream of Agiobologbo; CTR = Control</i>										
Source: Enwhe Field Development EIA Field Data September, 2016 (Wet season)										

Table 4.5f: Summary results of Microbiological measurements in Surface water around Enwhe Field during the dry season

Parameters	PW	PRoW	USPW	MSPW	DSPW	USAGIO	MSAGIO	DSAGIO	CTR
Coliform Count MPN/100ml	4.4±4.83	4.29±2.75	5±4.24	2±0	6.6±5.86	5±0	2±0	5±4.24	4±1.41
HUB cfu/ml x 10 ²	0.17±0.08	0.19±0.09	0.11±0.14	0.1±0	0.18±0.08	0.24±0	0.31±0	0.11±0.14	0.13±0.04
HUF cfu/ml x 10 ²	0.07±0.02	0.17±0.15	0.08±0	0±0	0.07±0.02	0±0	0.34±0	0.08±0	0±0
THB cfu/ml x 10 ³	0.37±0.21	0.38±0.2	0.34±0.16	0.34±0	0.39±0.21	0.45±0	0.29±0	0.34±0.16	0.23±0.05
THF cfu/ml x 10 ²	0.06±0.05	0.17±0.26	0.07±0	0.07±0	0.05±0.05	0±0	0.08±0	0.07±0	0.07±0

PW=Proposed Wells; PRoW=Pipeline RoW; USPW = Upstream of Proposed Wells; MSPW =Midstream of Proposed Wells; DSPW = Downstream of Proposed Wells; USAGIO = Upstream of Agioglobogbo; MSAGIO = Midstream of Agioglobogbo; DSAGIO = Downstream of Agioglobogbo; CTR = Control

Source: Enwhe Field Development EIA Field Data November,2016 (Dry season)

4.7.4 Sediment Quality

The summary of results of physicochemical measurements in sediments are presented in Tables 4.6a and 4.6b for the wet and dry seasons respectively. Detailed results are presented in Appendix 4.6.4a & b. All results are presented in relation to sampling strategy to cover the Proposed Wells (PW), Pipeline Right of Way (PRoW) and Pipeline River Crossings (near proposed wells and near Ogiogbologbo community).

Sediment Texture

The sediment composition in the study locations is presented in Fig. 4.2. During the dry season, sediments were dominated by sand with silt and clay contributing less than 20% at all locations but during the wet season the levels of silt and clay were comparable to sand and in some locations such as USAGIO and MSAGIO silt became dominant component of the sediment. This is attributed to inputs of silt and clay via surface run-off during the rainy season. Constant reworking of the sediments by river discharge leads to the dominant sand composition in the dry season.

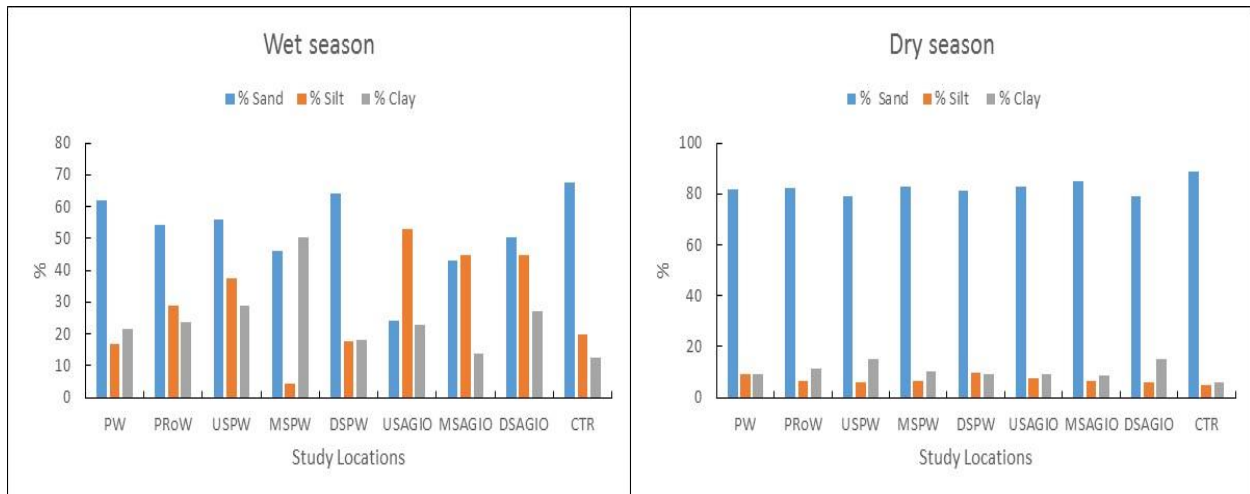


Fig. 4.2: Textural composition of sediment during wet and dry seasons in the study area

pH:

Average sediment pH ranged from mean of 5.11 at MSAGIO to 5.49 at PRoW compared to control of 6 during the wet season and from 5.2 at MSAGIO to 6.61 at USAGIO compared to 4.82 at the control during the dry season. There was no significant difference between study area and control. All sediment pH were acidic with relatively higher values during the dry season in study locations while the opposite trend was found at the control. The sediment pH is within the range of those expected in natural waters (Delaune and Reddy, 2005). Carbon dioxide from atmosphere and organic acid formed by decaying organic matter are the two sources of acidity in most near-surface environments, resulting in acidic pH values in the range 5 – 6. Lower pH is found in acid sulphate soils, where values as low as 4.0 are sometimes recorded. Ezekiel *et al.* (2011) reported a range of 5.06 to 5.86 in the sediments of Sombreiro River (Niger Delta).

Redox Potential:

The mean reduction-oxidation potential of the sediments ranged from 104.6 mV at MSAGIO to 112.6mV at USPW compared to control of 98.9 mV during the wet season and from 27.8 mV at USAGIO to 68.3 mV at USPW and DSAGIO compared to control of 98 mV during the dry season. Redox levels were significantly higher during the wet than dry season possibly due to the un-compacted nature of newly introduced sediments. During the wet season, control was lower than the study location but opposite trend was found during the dry season. The oxidation-reduction (redox) conditions in surface sediments depend on the degree of organic enrichment (Zobell, 1946). The sediment redox is within range expected in submerged sediments (+700 to -300 mV) (Delaune *et al.*, 1976). The generally oxidizing nature of the sediments is an indication of low levels of decomposable organic matter.

Electrical Conductivity

The mean conductivity of the sediments ranged from 30.2 $\mu\text{S}/\text{cm}$ at MSPW to 76.6 $\mu\text{S}/\text{cm}$ at USAGIO compared to control of 103.1 $\mu\text{S}/\text{cm}$ during the wet season and from 41.03 $\mu\text{S}/\text{cm}$ at USPW and DSAGIO to 114.32 $\mu\text{S}/\text{cm}$ at MSPW compared to control of 62.5 $\mu\text{S}/\text{cm}$ during the dry season. Conductivity was higher in control than study locations during wet season but there was no spatial variation during the dry season. Values during the dry season were also not significantly different from wet season levels. Conductivities are related to salt ions in the sediment. For instance, Ezekiel *et al.* (2011) reported sediment conductivities ranging from 40 to 1,940 $\mu\text{S}/\text{cm}$ in Sombreiro River. The highest level was obtained from the brackish ends of the river at Degema compared to others from the fresh water reaches of the river such as Ogbele. The conductivity levels measured are typical of freshwater environments.

Total Organic Carbon (TOC)

TOC ranged from mean of 0.05% at USAGIO to 0.17% at USPW and USAGIO compared to control of 0.16% during the wet season and from 0.09% at MSPW to 0.4% at USPW and DSAGIO compared to control of 0.09% during the dry season. Wet season values were relatively higher than those of the dry season. Studies on River Sombreiro in the Niger Delta (Ezekiel *et al.*, 2011) reported a range of 2.02 to 4.13%. Present values are therefore within known levels in sediments of the area. USEPA (2002) recommended the following assessment categories for TOC in sediments: Low: $\leq 1\%$, Intermediate: 1 to 3%, High: $>3\%$. TOC values encountered were generally lower than 1% in all stations. Natter *et al.* (2012) classified levels of TOC $<3\%$ as pristine sediments in contrast to levels of 10 – 28% for heavily oiled sediments. All values of TOC measured are therefore below those related to oil pollution.

Oil and Grease (O&G):

Oil and grease ranged from a mean of 4.2 ppm at USAGIO to 7.8 ppm at MSPW compared to control of 6.2 ppm during the wet season and from 4.3 ppm at USAGIO to 5.84 at DSPW compared to 3.9 ppm at the control during dry season. Wet season values were higher than dry season levels

showing the effect of rain-related surface run-off inputs. Oil and grease represents the total of all biogenic and mineral hydrocarbons. The sediments are not polluted with respect to hydrocarbons.

Total Hydrocarbons (THC)

THC ranged from a mean of 2.3 mg/kg at DSAGIO to 3.8 mg/kg at MSPW compared to the control of 1.8 mg/kg during the wet season and from 1.55 mg/kg at DSAGIO to 2.6 mg/kg at MSPW compared to control of 2.25 mg/kg during the dry season. Wet season values were significantly higher than dry season but spatial variations were not significant. The higher wet season levels reflect the effect of rain-related surface run-off inputs. THC represents the total of all biogenic and mineral hydrocarbons.

Nutrients-Ammonium, Nitrate, Sulphate

Ammonium ranged from a mean of 0.15 mg/kg at MSAGIO to 0.38 mg/kg at USAGIO compared to the control of 0.2 mg/kg during the wet season and from 0.19 mg/kg to 0.35 mg/kg at MSAGIO compared to the control of 0.17 mg/kg during the dry season. Wet season values were higher than dry season concentrations and study locations were higher than control.

Nitrate ranged from a mean of 0.52 mg/kg at MSAGIO to 2.66 mg/kg at MSPW compared to control of 3.1 mg/kg during the wet season and from 0.5 mg/kg at USAGIO to 2.48 mg/kg at MSPW compared to 0.67 mg/kg at the control during the dry season. Wet season values were higher than those of the dry season indicating the important of rain-related inputs from the catchment. Spatial variation was not significant except in the wet season when the control locations showed the highest concentration of nitrate. Previous studies in the Sombreiro River within the Niger Delta (Ezekiel *et al.*, 2011) reported a range of 2.6 to 4.1 mg/kg showing that the present measurements are normal for the area.

Sulphate ranged from a mean of 2.2 mg/kg at USAGIO to 7.86 mg/kg at MSPW compared to the control of 7.44 mg/kg during the wet season and from 0.19 mg/kg at DSAGIO to 0.28 mg/kg at PRow compared to control of 0.17 mg/kg during the dry season. Wet season was higher than dry season in all locations including control showing the importance of external loading via run-off during the rains. Studies in the Sombreiro River (Ezekiel *et al.*, 2011) gave values of sulphate from 21 to 30 mg/kg which are markedly higher than the levels reported for the present study. The present levels are therefore considered normal.

Total phosphorus ranged from a mean of 0.49 mg/kg at MSAGIO to 1.19 mg/kg at DSAGIO compared to control of 0.71 mg/kg during the wet season and from 0.7 mg/kg at DSAGIO to 2.6 mg/kg at USAGIO compared to control of 0.78 mg/kg during the dry season. There was no significant seasonal difference in total phosphorus levels in the sediments. Wide spatial variations with no clear trend in both seasons were observed.

Chloride (Cl-)

Chloride is an indicator of the salt content of the sediments. Concentrations ranged from a mean of 7.7 mg/kg at MSPW to 24.01 mg/kg at DSPW compared to the control of 32.5 mg/kg during the wet season and from 14.98 mg/kg at DSAGIO to 41.12 mg/kg at MSPW compared to control of 14.91 mg/kg. There was no significant seasonal and spatial variation in chloride levels. All concentrations were low reflecting the freshwater environment.

Table 4.6a: Summary results of Physicochemical measurements in aquatic sediments around Enwhe Field during the wet season

Parameters	PW	PRoW	USPW	MSPW	DSPW	USAGIO	MSAGIO	DSAGIO	CTR
	Mean±Std	Mean±Std	Mean±Std	Mean±Std	Mean±Std	Mean±Std	Mean±Std	Mean±Std	Mean±Std
% Sand	62±13.09	54.3±19.26	56.03±27.82	46.2	64.27±12.98	24	43.1	50.37±25.15	67.5±6.36
% Silt	16.67±11.49	28.86±21.63	37.33±32.15	4.3	17.54±9.27	53	44.7	44.67±26.1	20±1.41
% Clay	21.47±14.54	23.76±14.8	28.83±20.1	50.5	18.19±6.74	23	13.8	27.17±21.83	12.5±4.95
pH	5.3±0.82	5.49±0.78	5.17±0.71	5.21	5.46±1.01	5.13	5.11	5.3±0.64	6±0.02
Redox Potential (mV)	107.21±10.74	104.6±8.57	112.57±9.7	104.9	105.96±12.19	107.8	104.6	111.57±10.03	98.9±2.26
Electrical Conductivity (uS/cm)	61.49±33.21	62.44±31.54	45.6±31.73	30.2	70.33±41.74	76.5	39.2	58.3±32.39	103.1±7.35
TOC (%)	0.13±0.02	0.16±0.06	0.17±0.04	0.13	0.15±0.03	0.17	0.05	0.13±0.03	0.16±0.05
O & G (ppm)	6.79±1.02	6.91±1.42	6.23±1.05	7.8	6.3±1.11	4.2	7.4	6.6±0.61	6.2±0.28
NH ₄ ⁺ (mg/kg)	0.31±0.08	0.31±0.08	0.34±0.1	0.34	0.31±0.09	0.38	0.15	0.31±0.06	0.2±0.09
NO ₃ ⁻ (mg/kg)	1.36±0.9	2.12±1.46	1.7±1.26	2.66	1.12±0.74	2.1	0.52	1.82±1.08	3.1±3.19
SO ₄ ²⁻ (mg/kg)	6.19±2.35	7.11±7.66	3.31±0.25	7.86	7.12±4.38	2.2	3.63	3.66±0.41	7.44±0.54
Total Phosphorous (mg/kg)	1.13±0.51	1.17±0.56	1.18±0.88	0.77	1.18±0.49	1.52	0.49	1.19±0.88	0.71±0.36
Total Nitrogen (%)	0±0	0±0	0±0	0	0±0	0	0	0±0	0±0
THC (mg/kg)	2.86±0.82	3.06±0.65	2.67±0.9	3.8	2.9±0.78	2.8	2.5	2.3±0.44	1.8±0
Cl- (mg/kg)	20.61±13.41	16.32±8.86	15.33±10.21	7.7	24.01±15.91	12.2	11.9	19.97±10.42	32.5±4.67
PW=Proposed Wells; PRoW=Pipeline RoW; USPW = Upstream of Proposed Wells; MSPW =Midstream of Proposed Wells; DSPW = Downstream of Proposed Wells; USAGIO = Upstream of Agioglobogbo; MSAGIO = Midstream of Agioglobogbo; DSAGIO = Downstream of Agioglobogbo; CTR = Control									
Source: Enwhe Field Development EIA Field Data September,2016 (Wet season)									

Table 4.6b: Summary results of Physicochemical measurements in aquatic sediments around Enwhe Field during the dry season

Parameters	PW	PRoW	USPW	MSPW	DSPW	USAGIO	MSAGIO	DSAGIO	CTR
	Mean±Std	Mean±Std	Mean±Std	Mean±Std	Mean±Std	Mean±Std	Mean±Std	Mean±Std	Mean±Std
% Sand	81.9±2.52	82.25±3.75	78.94±5.11	83	81.01±2.8	82.88	84.97	78.94±5.11	88.92±5.21
% Silt	9.07±2.44	6.26±0.79	5.89±0.41	6.5	9.93±2.03	7.68	6.5	5.89±0.41	5.17±3.63
% Clay	9.03±1.41	11.49±4.18	15.18±5.52	10.5	9.06±1.45	9.44	8.53	15.18±5.52	5.92±1.58
pH	5.64±0.33	5.62±0.5	5.76±0.06	5.25	5.94±0.53	6.61	5.2	5.76±0.06	4.82±0.49
Redox Potential (mV)	57.34±16.05	65.93±21.09	68.3±15.7	61	49.36±22.43	27.8	85	68.3±15.7	98±48.65
Electrical Conductivity (uS/cm)	60.93±50.1	66.25±28.33	41.03±22.31	114.32	59.07±47.75	87.01	50.55	41.03±22.31	62.58±17.61
TOC (%)	0.23±0.11	0.29±0.15	0.4±0.05	0.09	0.29±0.08	0.43	0.29	0.4±0.05	0.09±0.02
O & G (ppm)	5.44±0.65	4.77±1.21	4.6±1.84	5.6	5.84±1.18	4.3	6.4	4.6±1.84	3.9±0.28
NH ₄ ⁺ (mg/kg)	0.21±0.06	0.28±0.08	0.19±0.01	0.27	0.19±0.05	0.284	0.35	0.19±0.01	0.17±0.14
NO ₃ ⁻ (mg/kg)	1.01±1.08	1.37±0.95	0.53±0.46	2.477	0.68±0.71	0.497	1.553	0.53±0.46	0.67±0.27
SO ₄ ²⁻ (mg/kg)	3.88±3.08	3.38±2.9	2.46±0.81	9.21	5.02±5.59	0.97	5.05	2.46±0.81	3.99±3.72
Total Phosphorous (mg/kg)	0.9±0.58	1.29±0.55	0.7±0.06	1.54	0.81±0.49	2.16	1.54	0.7±0.06	0.78±0.3
Total Nitrogen (%)	0±0	0±0	0±0	0.0017	0±0	0.0011	0.0023	0±0	0±0
THC (mg/kg)	1.74±0.54	1.8±0.4	1.55±0.49	2.4	1.5±0.43	2	1.9	1.55±0.49	2.25±0.07
Cl ⁻ (mg/kg)	21.7±13.11	20.84±9.68	14.98±5.46	41.12	19.71±9.74	21.4	21.12	14.98±5.46	14.91±6.26
PW=Proposed Wells; PRoW=Pipeline RoW; USPW = Upstream of Proposed Wells; MSPW =Midstream of Proposed Wells; DSPW = Downstream of Proposed Wells; USAGIO = Upstream of Agioglobogbo; MSAGIO = Midstream of Agioglobogbo; DSAGIO = Downstream of Agioglobogbo; CTR = Control									
Source: Enwhe Field Development EIA Field Data November,2016 (Dry season)									

Exchangeable cations and Heavy metals

The summary of results of cations and heavy metal measurements in sediments are presented in Tables 4.6c and 4.6d for the wet and dry seasons respectively. Detailed results are presented in Appendix 4.6.4c - f.

Sodium ranged from a mean of 17.51 mg/kg at USAGIO to 50.74 mg/kg at USPW compared to control of 14.54 mg/kg during the wet season and from 19.81 mg/kg at MSPW to 45.52 mg/kg at MSAGIO compared to control of 13 mg/kg during the dry season. There were no clear seasonal and spatial variations.

Potassium ranged from a mean of 9.45 mg/kg at DSPW to 27.37 mg/kg at USPW compared to control of 8.76 mg/kg during the wet season and from 12.98 mg/kg at MSPW to 46.27 mg/kg at USAGIO compared to control of 5.97 mg/kg. Control levels were generally lower than those of the study location but there were no clear spatial or seasonal trends.

Calcium ranged from a mean of 9.03 mg/kg at USAGIO to 20.75 mg/kg at PW compared to control of 21.73 mg/kg during the wet season and from 10.74 mg/kg at MSPW to 24.6 mg/kg at DSPW compared to control of 5.12 mg/kg during the dry season with no spatial or seasonal trend.

Magnesium ranged from a mean value of 8.91 mg/kg at MSAGIO to 17.02 mg/kg at MSPW compared to control of 8.13 mg/kg during the wet season and from 4.68 mg/kg at MSPW to 16.54 at DSAGIO compared with control of 3.12 mg/kg during the dry season. There were no significant spatial and seasonal variations. Sodium, potassium, calcium and magnesium are major cations related to total dissolved solids (salts). Their levels in sediment are usually strongly correlated with the levels in overlying water (Bohan and Hongxiao, 1994).

Iron and Manganese

Iron ranged from a mean of 4346.8 mg/kg at USAGIO to 7298.5 mg/kg at MSPW compared to control of 6294.7 mg/kg during the wet season and from 4695.9 mg/kg at DSPW to 5376.7 mg/kg at MSAGIO compared to control of 5259.1 mg/kg during the dry season. Wet season values were significantly higher than dry season concentrations but there were no significant spatial variation in relation to control. Iron is not usually considered as serious a pollutant and no limits are developed for it in sediments. Concentrations can vary widely in relation to the sedimentary geology of the area (RPI, 1984; Akpan *et al.*, 2002). All values were within those reported by RPI/NNPC (1985) for Niger Delta (420-22,700 mg/kg) and are considered normal for the area.

Table 4.6c: Summary results of Metals measurements in aquatic sediments around Enwhe Field during the wet season

Parameters	PW	PRoW	USPW	MSPW	DSPW	USAGIO	MSAGIO	DSAGIO	CTR
	Mean±Std	Mean±Std	Mean±Std	Mean±Std	Mean±Std	Mean±Std	Mean±Std	Mean±Std	Mean±Std
Na (meq/100g)	21.19±11.87	39.15±24.08	50.74±33.15	37.73	18.48±11.03	17.51	19.7	37.88±29.32	14.54±1.22
K (meq/100g)	9.83±7.04	19.65±14.38	27.37±24.11	22.67	9.45±7.45	12.47	11.85	21.29±18.98	8.76±0.73
Ca (meq/100g)	20.75±21.21	15.6±8.55	15.71±3.54	18.15	20.2±19.77	9.03	9.5	13.13±4.33	21.73±5.56
Mg (meq/100g)	9.18±6.58	14.27±6.03	15.45±3.77	17.02	9.21±6.72	14.2	8.91	13.89±3.89	8.13±8.35
Fe (mg/kg)	6160.4±1247.39	6286.36±1176.34	6738.6±900.74	7298.53	5573.55±1551.87	4346.78	6456.67	6738.6±900.74	6294.76±197.76
Cu (mg/kg)	1.47±0.96	1.65±0.92	1.95±1.27	0.9	1.51±0.94	2.04	0.51	1.95±1.27	0.84±0.27
Zn (mg/kg)	37.21±5.14	40.18±4.4	37.82±5.13	43.09	36.61±4.55	40.26	32.85	37.82±5.13	32.23±2.16
V (mg/kg)	<0.05±0	<0.05±0	<0.05±0	<0.05	<0.05±0	<0.05	<0.05	<0.05±0	<0.05±0
Pb (mg/kg)	3.78±1.33	4.27±1.8	4.06±2.41	2.86	3.67±1.46	5.46	3.13	4.06±2.41	6.43±1.02
Cd (mg/kg)	0.7±0.21	0.71±0.14	0.74±0.06	0.51	0.71±0.21	0.49	0.62	0.74±0.06	0.77±0.06
Ni (mg/kg)	4.4±0.59	4.72±1.34	5.6±1.98	4.38	4.21±0.8	6.08	3.79	5.6±1.98	4.97±0.22
Cr (mg/kg)	0.54±0.26	0.5±0.53	1.1±0.61	0.45	0.59±0.28	0.22	0.09	1.1±0.61	0.75±0.28
<p><i>PW=Proposed Wells; PRoW=Pipeline RoW; USPW = Upstream of Proposed Wells; MSPW =Midstream of Proposed Wells; DSPW = Downstream of Proposed Wells; USAGIO = Upstream of Agiobologbo; MSAGIO = Midstream of Agiobologbo; DSAGIO = Downstream of Agiobologbo; CTR = Control</i></p> <p>Source: Enwhe Field Development EIA Field Data September,2016 (Wet season)</p>									

Table 4.6d: Summary results of Metals measurements in aquatic sediments around Enwhe Field during the dry season

Parameters	PW	PRoW	USPW	MSPW	DSPW	USAGIO	MSAGIO	DSAGIO	CTR
	Mean±Std	Mean±Std	Mean±Std	Mean±Std	Mean±Std	Mean±Std	Mean±Std	Mean±Std	Mean±Std
Na (meq/100g)	31.33±14.07	32.66±22.08	23.9±12.35	19.81	30.39±15.16	76.64	45.52	23.9±12.35	13±3.07
K (meq/100g)	14.94±3.76	20.62±12.8	15.49±8.16	12.98	16.03±3.84	46.27	27.14	15.49±8.16	5.97±2.02
Ca (meq/100g)	24.02±18.03	14.73±4.29	18.34±0.08	10.74	24.6±17.53	13.11	20.45	18.34±0.08	5.12±1.61
Mg (meq/100g)	8.37±3.71	13.12±5.54	16.54±0.14	4.68	10.41±3.96	10.35	21.52	16.54±0.14	3.12±2.21
Fe (mg/kg)	4841.66±26 8.14	4924.28±52 9.16	5154.65±92 6.61	5006.04	4695.97±34 3.73	4833.44	5376.74	5154.65±92 6.61	5259.15±15 9.69
Cu (mg/kg)	2.92±1.38	3.28±2.01	2.99±0.27	1.64	2.87±1.44	6.87	1.46	2.99±0.27	3.16±1.16
Zn (mg/kg)	31.46±8.14	36.91±10.91	47.09±4.16	25.77	30.76±8.87	48.27	23.08	47.09±4.16	42.58±3.69
V (mg/kg)	<0.05±0	<0.05±0	<0.05±0	<0.05	<0.05±0	<0.05	<0.05	<0.05±0	<0.05±0
Pb (mg/kg)	7.05±1.31	7.99±0.92	7.2±0.5	8.6	6.55±1.01	8.77	6.77	7.2±0.5	2.63±0.71
Cd (mg/kg)	0.59±0.09	0.55±0.09	0.56±0.16	0.51	0.59±0.09	0.68	0.59	0.56±0.16	0.53±0.03
Ni (mg/kg)	4.92±1.39	5.38±0.73	5.27±0.9	5.21	4.57±1.51	5.21	6.71	5.27±0.9	5.26±0.03
Cr (mg/kg)	0.12±0.05	0.11±0.04	0.17±0.04	0.09	0.13±0.05	0.08	0.08	0.17±0.04	0.19±0.06
<i>PW=Proposed Wells; PRoW=Pipeline RoW; USPW = Upstream of Proposed Wells; MSPW =Midstream of Proposed Wells; DSPW = Downstream of Proposed Wells; USAGIO = Upstream of Agiogbologbo; MSAGIO = Midstream of Agiogbologbo; DSAGIO = Downstream of Agiogbologbo; CTR = Control</i>									
Source: Enwhe Field Development EIA Field Data November,2016 (Dry season)									

Copper(Cu)

Copper ranged from a mean 0.51 mg/kg at MSAGIO to 1.95 mg/kg at DSAGIO compared to control of 0.84 mg/kg during the wet season and from 1.46 mg/kg at MSAGIO to 3.28 mg/kg at PRow compared to 3.16 mg/kg during the dry season. Dry season values were significantly higher than wet season concentrations but there was no significant difference between control and study locations.

Zinc (Zn)

Zinc ranged from a mean value of 32.85 mg/kg at MSAGIO to 43.09 mg/kg at MSPW compared to control of 32.23 mg/kg in the wet season and from 23.08 mg/kg at MSAGIO to 48.27 mg/kg at USAGIO compared to 42.58 mg/kg at control during the dry season. There were no significant differences between seasons and between study locations and control. Measured values are within those reported by RPI/NNPC (1985) for the Niger Delta (1.8-76 mg/kg).

Vanadium (V)

Vanadium was not detected in the study area and control in both seasons.

Lead (Pb)

Lead ranged from a mean of 2.86 mg/kg at MSPW to 4.27 mg/kg at PRow compared to 6.43 mg/kg at the control during the wet season and from 6.77 mg/kg at MSAGIO to 7.99 mg/kg at PRow compared to 2.63 mg/kg at the control during the dry season. Dry season values were significantly higher than wet season values but control was significantly different from study locations in both seasons. RPI/NNPC (1985) reported a range of BDL to 37 mg/kg.

Cadmium (Cd)

Cadmium ranged from a mean of 0.49 mg/kg at USAGIO to 0.74 mg/kg at USPW compared to control of 0.77 mg/kg and from 0.51 mg/kg at MSPW to 0.59 mg/kg at DSPW compared to mean of 0.53 mg/kg during the dry season. Wet season values were relatively higher than dry season values. RPI/NNPC (1985) reported a range of BDL to 8 mg/kg.

Nickel (Ni)

Nickel ranged from a mean of 3.79 mg/kg at MSAGIO to 6.08 mg/kg at USAGIO compared to 4.97 mg/kg at the control during the wet season and from 4.57 mg/kg at DSPW compared to 5.26 mg/kg at control. There were no significant seasonal and spatial differences in relation to the control. RPI/NNPC (1985) reported a range of BDL-28.6 mg/kg.

Chromium (Cr)

Chromium ranged from a mean of 0.09 mg/kg at MSAGIO to 1.1 mg/kg at DSAGIO compared to 0.75 mg/kg at the control during the wet season and from 0.08 mg/kg at MSAGIO to 0.17 mg/kg at DSAGIO compared to 0.19 mg/kg at the control during the dry season. Wet season was

significantly higher than dry season values but control was not significantly different from study locations. The proposed project has the potential to introduce heavy metals and exchangeable cations into the environment through waste and effluent discharges.

Sediment Microbiology

The summary of results of microbiological measurements in sediments are presented in Tables 4.6e and 4.6f for the wet and dry seasons respectively. Detailed results are presented in Appendix 4.6.4r & h.

Total Heterotrophic Bacteria (THB)

THB ranged from a mean of 1.23×10^4 cfu/g at USAGIO to 2.67×10^4 cfu/g at PW compared to 2.83×10^4 cfu/g at the control during the wet season and from 0.76×10^4 cfu/g at DSAGIO to 1.85×10^4 cfu/g at PRow compared to 2.16×10^4 cfu/g at the control during the dry season.

Hydrocarbon Utilizing Bacteria (HUB)

HUB ranged from a mean of 0.37×10^3 cfu/g at MSAGIO to 0.57×10^3 cfu/g at PW compared to 0.21×10^3 at control during the wet season and from 0.11×10^3 cfu/g at USAGIO to 0.83×10^3 cfu/g at MSPW compared to 0.14×10^3 cfu/g at control during the dry season. There were no significant seasonal and spatial variation in relation to control.

Total Heterotrophic Fungi (THF)

THF range from a mean of 0.22×10^3 cfu/g at MSAGIO to 0.59×10^3 cfu/g at PW compared to control of 0.93×10^3 cfu/g during the wet season and from 0.37×10^3 cfu/g at PW to 0.91×10^3 cfu/g at USAGIO compared to 0.25×10^3 cfu/g at control. There were no significant spatial and seasonal variation in relation to the control.

The percentage of HUB to THB is usually used as indication of petroleum hydrocarbon pollution. Levels below 10% is regarded as indicator of unpolluted environment (Atlas, 1982). The ratios of HUB to THB were well below 10%, signifying absence of oil pollution in the environment.

Table 4.6e: Summary results of Microbiological measurements in aquatic sediments around Enwhe Field during the wet season

Parameters	PW	PRoW	USPW	MSPW	DSPW	USAGIO	MSAGIO	DSAGIO	CTR
	Mean±Standard	Mean±Standard	Mean±Standard	Mean±Standard	Mean±Standard	Mean±Standard	Mean±Standard	Mean±Standard	Mean±Standard
(THB) x 10 ⁴ (cfu/g)	2.67±1.62	2.25±1.45	1.9±1.61	1.76	2.53±1.75	1.23	2.5	1.9±1.61	2.83±1.91
(THF) x 10 ³ (cfu/g)	0.59±0.27	0.48±0.18	0.59±0.21	0.43	0.48±0.18	0.43	0.22	0.59±0.21	0.93±0.93
(HUB) x 10 ³ (cfu/g)	0.57±0.27	0.51±0.2	0.46±0.14	0.98	0.57±0.27	0.49	0.37	0.46±0.14	0.21±0.09
(HUF) x 10 ² (cfu/g)	0.04±0.01	0.13±0.09	0.12±0.11	0.05	0.05±0.02	0.12	0.15	0.12±0.11	0.04±0
<p><i>PW=Proposed Wells; PRoW=Pipeline RoW; USPW = Upstream of Proposed Wells; MSPW =Midstream of Proposed Wells; DSPW = Downstream of Proposed Wells; USAGIO = Upstream of Agiobologbo; MSAGIO = Midstream of Agiobologbo; DSAGIO = Downstream of Agiobologbo; CTR = Control</i></p>									
<p>Source: Enwhe Field Development EIA Field Data September,2016 (Wet season)</p>									

Table 4.6f: Summary results of Microbiological measurements in aquatic sediments around Enwhe Field during the dry season

Parameters	PW	PRoW	USPW	MSPW	DSPW	USAGI O	MSAGI O	DSAGIO	CTR
	Mean±Std	Mean±Std	Mean±Std	Mean±Std	Mean±Std	Mean±Std	Mean±Std	Mean±Std	Mean±Std
(THB) x 10 ⁴ (cfu/g)	1.66±0.41	1.85±1.27	0.76±0.28	1.3	1.82±0.39	3.74	1.4	0.76±0.28	2.16±1.81
(THF) x 10 ³ (cfu/g)	0.37±0.15	0.58±0.26	0.45±0.47	0.39	0.44±0.22	0.91	0.59	0.45±0.47	0.255±0.19
(HUB) x 10 ³ (cfu/g)	0.5±0.25	0.55±0.35	0.52±0.3	0.83	0.45±0.19	0.11	0.92	0.52±0.3	0.14±0
(HUF) x 10 ² (cfu/g)	0.06±0.02	0.08±0.03	0.09±0.06	0.09	0.05±0.02	0.09	0.08	0.09±0.06	0.075±0.04
<i>PW=Proposed Wells; PRoW=Pipeline RoW; USPW = Upstream of Proposed Wells; MSPW =Midstream of Proposed Wells; DSPW = Downstream of Proposed Wells; USAGIO = Upstream of Agiogbologbo; MSAGIO = Midstream of Agiogbologbo; DSAGIO = Downstream of Agiogbologbo; CTR = Control</i>									
Source: Enwhe Field Development EIA Field Data November,2016 (Dry season)									

4.7.5: Soil quality

Soil Physical Properties

The summary results of physicochemical properties of soils in the study area is presented in Table 4.7 a & b for surface and subsurface soils respectively. Detailed Results are presented in Appendix 4.6.5.1a & b for wet and dry seasons respectively. The physicochemical results are presented in terms of the sampling strategy covering surface (0-15 cm) and subsurface (15-30 cm) soils around the Proposed Pipeline area (PW) and Pipeline Right of Way (PRoW) for the wet and dry season.

Soil Particle size distribution and Texture

At the Proposed Wells area (PW) surface soil (0 – 15 cm) was composed of sand (64.3%), silt (15.7 %) and clay (20 %) with a Clay loam texture compared to the control location which was Sandy loam in the wet season. In the dry season, the soil texture changed to sandy loam at the surface (0 – 15 cm) layer. The wet season soil has higher proportions of clay and silt but lower sand fraction relative to the dry season soil.

At the pipeline RoW (PRoW), the surface (0 – 15 cm) soil texture was Sandy Clay Loam in the wet season with particle size comprising of 69.37% sand, 12.4% silt and 19.3% clay. In the dry season, the texture changed to Loamy Sand with particle size distribution of 75% sand, 10% Silt, and 15% Clay. The control location had similar texture within the wet and dry seasons. The wet season soil has slightly higher silt and clay fractions but lower sand fraction than the dry season soil.

Sub-surface (15 – 30 cm) soils collected at the proposed well sites were Sandy Clay Loam in texture in the wet season and Loamy Sand texture in the dry season. The control soil samples had similar texture to those around the proposed well sites. Subsurface soil from the PRoW had a Loamy Sand texture in the wet season with 74% sand, 10 % silt and 16% clay. Soil collected in the dry season from the same depth showed a Loamy Sand texture with 78 % sand, 9 % silt and 13 % clay content. The soil textures of the controls were loamy sand and sandy loam for wet and dry seasons respectively. The generally light textures of the soils will permit good drainage and aerobic conditions within the soil.

Table 4.7a: Summary of Surface Soil (0 -15cm) Physicochemical properties in the study area

Soil Properties	Proposed Wells (PW)				Pipeline Right of Way (PRoW)			
	Wet Season		Dry Season		Wet Season		Dry Season	
	Mean	Control	Mean	Control	Mean	Control	Mean	Control
pH	4.657±0.59	5.385±1.12	5.08±0.71	5.08±0.71	5.58±1.02	5.39±1.12	4.91±0.7	5.92±0.42
Electrical Conductivity (uS/cm)	62.872±31.56	105.95±98.36	66.87±25.89	66.87±25.89	62.83±32.18	105.95±98.36	49.85±28.15	67.7±19.94
TOC (‰)	0.125±0.05	0.17±0.11	0.55±0.38	0.55±0.38	0.14±0.05	0.17±0.11	0.45±0.29	0.25±0.22
O & G (mg/kg)	2.369±1.31	2.9±1.41	1.67±0.65	1.67±0.65	2.53±1.07	2.9±1.41	1.65±0.73	3.4±1.7
NH ₄ ⁺ (mg/kg)	0.158±0.06	0.114±0	0.17±0.02	0.17±0.02	0.16±0.05	0.11±0	0.18±0.03	0.31±0
NO ₃ ⁻ (mg/kg)	5.442±3.41	4.952±6.51	1.59±0.95	1.59±0.95	3.32±2.79	4.95±6.51	1.35±1.26	2.22±1.25
SO ₄ ²⁻ (mg/kg)	2.848±1.38	2.342±1.84	3.63±1.04	3.63±1.04	2.99±1.46	2.34±1.84	3.37±0.79	2.9±0.2
Total Phosphorus (mg/kg)	1.609±0.81	1.258±0.15	2.3±1.81	2.3±1.81	2.07±1.07	1.26±0.15	1.83±1.24	1.57±0.5
Total Nitrogen (%)	0.002±0	0.001±0	0±0	0±0	0±0	0±0	0±0	0±0
Bulk Density (g/cm ³)	0.238±0.04	0.2±0	0.35±0.16	0.35±0.16	0.23±0.06	0.2±0	0.36±0.17	0.27±0.2
THC (mg/kg)	0.867±0.48	1.2±0.14	0.84±0.53	0.84±0.53	0.95±0.37	1.2±0.14	0.9±0.42	0.75±0.49
Phenol (mg/kg)	#DIV/0!	±	<0.1±<0.1	<0.1±<0.1	#DIV/0!	#DIV/0!	<0.05±<0.05	<0.05±<0.05
Porosity (% pore space)	44.869±7.48	37.85±16.48	49.93±4.75	49.93±4.75	45.93±8.37	37.85±16.48	50.82±4.4	56.35±0.49
Permeability (K-4 cm/hr)	1.214±0.29	1.05±0.07	1.05±0.35	1.05±0.35	1.2±0.22	1.05±0.07	1.31±0.46	1.2±0.57
Cl ⁻ (mg/kg)	18.823±11.64	41.3218±37.41	17.95±10	17.95±10	19.19±10.42	41.33±37.41	13.94±8.93	18.29±6.5
% Sand	64.263±24.5	87.55±0.07	76.83±19.59	76.83±19.59	69.58±21.15	87.55±0.07	75.46±18.64	79±7.07
% Silt	15.723±15.59	0.525±0.18	10.03±12.24	10.03±12.24	12.44±13.75	0.53±0.18	9.5±10.6	9.3±6.65
% Clay	20.034±13.25	11.9±0.14	13.13±9.44	13.13±9.44	19.03±11.16	11.90.14	15.04±10.02	11.7±0.42

Source: Enwhe Field Data for Wet Season (September) and Dry season (November), 2016

Table 4.7b: Summary of Subsurface Soil (15-30 cm) Physicochemical properties in the study area

Soil Properties	Proposed Wells (PW)				Pipeline Right of Way (PRoW)			
	Wet Season		Dry Season		Wet Season		Dry Season	
	Mean	Control	Mean	Control	Mean	Control	Mean	Control
pH	4.76±0.53	5.865±0.81	5.11±0.7	5.11±0.7	5.46±0.94	5.87±1.14	5.02±0.79	5.21±0.01
Electrical Conductivity (uS/cm)	49.664±26.7	83.595±70.11	58.6±28.01	58.6±28.01	61.86±46.38	83.6±99.14	54.62±31.18	61.4±35.07
TOC (‰)	0.118±0.05	0.21±0.08	0.61±0.4	0.61±0.4	0.11±0.06	0.21±0.11	0.51±0.29	0.77±0.47
O & G (mg/kg)	2.843±1.38	2.75±0.45	1.23±0.67	1.23±0.67	2.56±1.16	2.75±0.64	1.41±0.79	2±0.57
NH ₄ ⁺ (mg/kg)	0.162±0.09	0.165±0.05	0.17±0.02	0.17±0.02	0.15±0.06	0.17±0.07	0.18±0.02	0.18±0
NO ₃ ⁻ (mg/kg)	4.812±3.27	4.876±4.44	1.46±0.77	1.46±0.77	2.94±2.6	4.88±6.28	1.44±1.12	2.22±0.63
SO ₄ ²⁻ (mg/kg)	2.832±1.45	3.283±0.09	3.62±0.97	3.62±0.97	2.75±1.57	3.28±0.13	3.43±0.86	2.93±0.5
Total Phosphorus (mg/kg)	1.806±1.16	1.316±0.07	2.27±1.63	2.27±1.63	1.94±1.34	1.32±0.1	1.66±0.87	1.62±0
Total Nitrogen (‰)	0.001±0	0.001±0	0±0	0±0	0±0	0±0	0±0	0±0
Bulk Density (g/cm ³)	0.22±0.04	0.165±0.02	0.39±0.16	0.39±0.16	0.21±0.06	0.17±0.02	0.34±0.13	0.33±0.13
THC (mg/kg)	1.069±0.46	0.85±0.15	0.93±0.62	0.93±0.62	0.92±0.43	0.85±0.21	0.72±0.49	0.3±0.14
Phenol (mg/kg)	<0.1±<0.1	<0.1±<0.1	<0.1±<0.1	<0.1±<0.1	<0.1±<0.1	<0.1±<0.1	<0.05±<0.05	<0.05±<0.05
Porosity (% pore space)	42.581±7.56	34.245±4.64	50.49±4.8	50.49±4.8	44.59±9.59	34.25±6.57	51.73±4.43	55.8±3.39
Permeability (K-4 cm/hr)	1.277±0.326	1.2±0.3	1.21±0.36	1.21±0.36	1.15±0.31	1.2±0.42	1.29±0.44	1.8±0.14
Cl ⁻ (mg/kg)	16.066±9.67	30.868±24.28	16.72±8.32	16.72±8.32	18.7±13.78	30.87±34.33	14.42±9.1	17.78±11.32
% Sand	64.435±17.74	63±24	78.08±20.06	78.08±20.06	73.54±18.69	63±33.94	77.47±17.84	75.5±2.12
% Silt	13.692±9.65	15.35±13.35	9.98±12.55	9.98±12.55	10.43±12.11	15.35±18.88	9.21±12.45	7.7±7.78
% Clay	21.928±14.07	21.65±10.65	11.94±9.65	11.94±9.65	16.07±12.85	21.65±15.06	13.32±7.63	16.8±9.9

Source: Enwhe Field Data for Wet Season (September) and Dry season (November), 2016

Soil Porosity and Permeability

Soil porosity refers to the space between soil particles, which consists of various amounts of water and air. Porosity depends on both soil texture and structure. A coarse soil has bigger particles than a fine soil, but it has less porosity, or overall pore space. Water can be held tighter in small pores than in large ones, so fine soils (e.g. silty loam) can hold more water than coarse soils (e.g. sandy loam). Mean porosity recorded for the wet season at the surface (0 – 15 cm) soil was 45% at the proposed wellsite and 46 % at the pipeline RoW. The corresponding sub-surface (15 – 30 cm) soils have mean porosity of 43 % at the proposed well site and 45 % at the pipeline RoW. Mean porosity of the dry season surface (0 – 15 cm) soil samples were 50 % for proposed well site and 51% for the pipeline RoW soil. The control sites have mean soil porosity of 50 % and 56 % for proposed well and pipeline RoW sites respectively. For sub-surface (15 – 30 cm) soil mean porosity was 50 % for proposed well site and 52 % for pipeline RoW. Generally, mean porosity was higher in the dry season soils relative to the wet season soils. The higher porosity in the dry season is indicative of the prevailing low soil moisture relative to air.

Permeability

Permeability is important when considering the rate at which waste liquid will percolate into soil. If the waste liquid percolates too fast, the soil will not have a chance to treat it and the waste liquid may seep into and contaminate the groundwater. If the waste liquid does not percolate fast enough, it may overflow to the ground surface, causing serious health hazards. Different types of soils have different soil permeability and percolate waste liquid at different rates. Some types of soil are acceptable for disposal systems, but others are not. Mean permeability of surface soil (0 – 15 cm) in the wet season was 1.214 ± 0.29 cm/hr in the proposed well site and 1.2 ± 0.22 cm/hr in the pipeline RoW. At the subsurface (15 – 30) soil permeability in the wet season was 1.27 ± 0.32 cm/hr in the proposed well site and 1.15 ± 0.31 cm/hr in the pipeline RoW site. In the dry season, surface soil (0 -15 cm) permeability was 1.05 ± 0.35 in the proposed well site and 1.21 ± 0.36 cm/hr in the pipeline RoW. The corresponding soil permeability of the sub-surface (15 – 30) samples was 1.2 ± 0.36 cm/hr in the proposed well site and 1.29 ± 0.44 cm/hr in the pipeline RoW. The permeability values were lower than the critical level of 5 cm/hr. Permeability is classified as rapid at >25 cm/hr and very slow at 0.13 cm/hr. All levels fell within moderately slow permeability class (Plant and soil science, 2017) which is good for the ground waters.

Soil Bulk Density

Mean bulk density values at the surface (0 – 15 cm) soils were 0.238 g/cm^3 in the wet season and 0.35 g/cm^3 in the dry season at the proposed well site. Values at the controls were 0.2 g/cm^3 and 0.35 g/cm^3 . In the pipeline RoW, bulk density of the surface soil (0 – 15 cm) was 0.23 g/cm^3 in the wet season and 0.36 g/cm^3 in the dry season. At the proposed well site, sub-surface (15 – 30 cm) bulk density was 0.22 g/cm^3 in the wet season and 0.39 g/cm^3 in the dry season compared to the control site of 0.165 g/cm^3 and 0.39 g/cm^3 in the wet and dry seasons respectively. At the pipeline RoW, the sub-surface (15 – 30 cm) bulk density was 0.21 g/cm^3 in the wet season and

0.34g/cm³ in the dry season compared controls of 0.17 g/cm³ and 0.33 g/cm³ respectively. The bulk densities obtained are generally low and in agreement with the soil porosity. Bulk density is the weight of soil for a given volume eg grams per cubic centimeter. Most good agricultural soils containing some organic matter have a bulk density of less than 1 g/m³, often 0.8 – 0.9 g/m³. Compost is around 0.5 g/m³. Mineral subsoils often have bulk densities around 1.4 g/m³ (Apps, 2016). The bulk densities fell within acceptable levels for agricultural soils.

Soil Chemical Properties

The summary results of Chemical properties of soils in the study area is presented in Table 4.7a & b for surface and subsurface soils respectively. Detailed Results are presented in Appendix 4.6.5.1a & b for wet and dry seasons respectively. The results are presented in terms of the sampling strategy covering surface (0-15 cm) and subsurface (15-30 cm) soils around the Proposed Pipeline area (PW) and Pipeline Right of Way (PRoW) for the wet and dry season

Soil Reaction and Electro-conductivity

At the proposed well site, top soil (0 – 15 cm) pH was strongly acid (4.65) in the wet season and moderately acid (5.08) in the dry season. The pH of the Control was 5.38 and 5.08 in the wet and dry seasons respectively. At the subsurface (15 – 30 cm) soil depth, soil pH was 4.76 in the wet season and 5.11 in the dry season. The corresponding values for the control were 5.86 and 5.11 respectively. Soil pH was generally lower in the wet season than in the dry season. In each season, soil pH was similar at both soil depths.

At the pipeline right of way (RoW), surface soil (0 – 15 cm) pH was moderately acid (5.58) in the wet season and strongly acid (4.91) in the dry season. The control sites had pH values of 5.39 and 5.92 in the wet and dry seasons respectively. Sub-surface (15 – 30) soil pH values for the same location were 5.46 and 5.02 for the wet and dry seasons respectively. Slightly acid to neutral soil pH (6 – 7) is most favourable to both biological life in soil and supply of nutrients to plants. Apps (2016) recommends a pH of 5.5-7.5 for good agricultural soils. A number of soil locations showed pH below 5.5 making the soils unsuitable for agriculture without proper management.

Electrical conductivity of the soils ranged from a mean of 49.66 µS/cm at the proposed wells to 61.86 µS/cm at the PRoW during the wet season and from 54.62 µS/cm at the PRoW to 58.6 µS/cm at the PW during the dry. Levels at the controls (83.59 µS/cm at PW and 83.6 µS/cm at PRoW) during the wet season were higher than at the study locations. The range of values shows that the soils are not saline as values obtained were below 2000 µS/cm (Apps, 2016). NSW (2004) recommends levels <0.15dS/m = 150 µS/cm. All measured values were within acceptable range

Total Organic Carbon (TOC)

At the surface depth, TOC ranged from 0.12% at PW during the wet season to 0.55% at PW during the dry season. At the control, values ranged from 0.17% at PRoW during the wet season to 0.55%

during the dry season at PW. At the subsurface level Total Organic Carbon at the PW was 0.118% compared to control of 0.21% during the wet season and 0.61% compared to control of 0.61% during the dry season. At the PRow mean TOC was 0.11% during the wet season compared to control of 0.21% and 0.51% compared to control of 0.77% during the dry season. Dry season values were generally higher than the wet season and controls were relatively higher than study locations. TOC values were higher at the surface than subsurface levels. Organic carbon is a measure of the organic matter in the soil. It includes undecomposed plant litter, soil organisms and humus. Soil organic carbon stores important nutrients, stabilizes soil structure and feeds soil microbes. Measured levels were low compared with the preferred level of > 2% for good agriculture. Apps (2016) recommends >5% organic matter for good soils which is 2.9% TOC. All values were lower than this threshold making the soils poor for agriculture.

Oil & Grease (O&G) and Total Hydrocarbons (THC)

O&G: Oil & Grease represents the sum of all biogenic and petroleum hydrocarbons.

At the surface soils Oil & Grease ranged from .65 mg/kg during the dry season at PRow to 2.53 mg/kg during the wet season at PRow compared to control of 1.67 mg/kg at PW during the dry season to 3.4 mg/kg at PRow during the dry season. At the subsurface depth, mean concentration of oil and grease ranged from 1.23 mg/kg during the dry season at PW to 2.84 mg/kg during the wet season at PW compared to control of 1.23 mg/kg during the dry season at PW to 2.75 mg/kg during the wet season at PW and PRow. Wet season values were higher than those of the dry season. Controls were higher than study locations along the PRow. Values were higher at the surface than subsurface levels. The oil and grease values are low and below levels of environmental concern (100 mg/kg) given by Beyer (1990).

THC: Total hydrocarbon is a related parameter to O&G and represents the sum of all biogenic and mineral hydrocarbons. Levels of THC at the surface soils ranged from 0.84 mg/kg at PW during the dry season to 0.95 mg/kg at PRow during the wet season compared to control of 0.75 mg/kg during the dry season at PRow to 1.2 mg/kg at PW during the wet season. At the subsurface level, THC ranged from 0.72 mg/kg at the PRow during the dry season to 1.07 mg/kg during the wet season at PW. At the controls values ranged from 0.3 mg/kg during the dry season at PRow to 0.93 mg/kg during the dry season at PW. THC was relatively higher at the surface than subsurface levels. The values were low and below levels of environmental concern in soils (100 mg/kg).

Nutrients

Ammonium: At the surface soil level, Ammonium ranged from 0.158 mg/kg at PW during the wet season to 0.18 mg/kg at PRow during the dry season compared to control of 0.11 mg/kg at PRow during wet season to 0.31 mg/kg at PRow during the dry season. At the subsurface level, ammonium ranged from 0.15 mg/kg at PRow during the wet season to 0.18 mg/kg at PRow during the dry season compared to control of 0.16 mg/kg at PW during the dry season to 0.18 mg/kg at

PRoW during the dry season. Ammonium varied widely with no difference between surface and bottom levels but controls were relatively higher than study locations.

Nitrate: Nitrate ranged from 1.35 mg/kg at PRoW during the dry season to 5.44 mg/kg at PW during the wet season compared to control of 1.59 mg/kg at PW during the dry season to 4.95 mg/kg at PW during the wet season at the surface level. At the subsurface level, nitrate ranged from 1.44 mg/kg at PRoW during the dry season to 4.81 mg/kg at PW during the wet season compared to control of 1.46 mg/kg at PW during the dry season to 4.88 mg/kg at Prow during the wet season. Nitrate levels were relatively higher at surface than subsurface levels and during the dry than wet season. Good quality soils should have nitrate levels >10 ppm (NWS, 2004). All measured values were low compared to the preferred level. According to Apps (2016), 2 ppm is considered low for agriculture. Values were generally below 2 ppm at most locations.

Total Nitrogen: At the surface and subsurface levels total nitrogen was very low or undetectable at most locations and control during the wet and dry seasons.

Total Phosphorus: Mean levels of total phosphorus at the surface levels ranged from 1.6 mg/kg at PW during the wet season to 2.3 mg/kg at PW during the dry season compared to control of 1.25 mg/kg at PW during the wet season to 2.3 mg/kg at PW during the dry season. At the subsurface level, total phosphorus ranged from 1.66 mg/kg at PRoW during the dry season to 2.27 mg/kg at PW during the dry season compared to control of 1.31 mg/kg at PW during the wet season to 2.27 mg/kg at PW during the dry season. There was no significant different between surface and subsurface levels and between control and study locations as well as between dry and wet seasons .For good soils total phosphorus should be greater than 20 ppm depending on land use (NWS, 2004). According to Apps (2016) 30 ppm phosphate is low while 150 ppm is high (10-50 ppm as total phosphorus). The levels of phosphorus were all below 10 pmm making the soils nutrient poor with respect to agricultueal use.

Sulphate and Chloride:

Sulphate: At the surface soil level, sulphate ranged from 2.84 mg/kg at PW during the wet season to 3.63 mg/kg at PW during the wet season compared to control of 2.34 mg/kg at PW during the wet season to 3.63 mg/kg at PW during the dry season. At the subsurface level, sulphate ranged from 2.75 mg/kg at PRoW during the wet season to 3.62 mg/kg at PW during the dry season compared to control of 2.93 mg/kg at PRoW during the dry season to 3.62 mg/kg during the dry season at PW. There was no significant spatial and seasonal differences in relation to control. Sulphate levels below 10 mg/kg are considered unsatisfactory for agricultural soils. Satisfactory levels should range between 15 and 45 mg/kg (Apps, 2016)

Chloride: At the surface levels, chloride ranged from 13.94 mg/kg at PRoW during the dry season to 19.19 mg/kg at PRoW during the wet season compared to control of 17.95 mg/kg at PW during

the dry season to 41.33 mg/kg at PRow during the wet season. At the subsurface levels, chloride ranged from 14.42 mg/kg at PRow during the dry season to 18.7 mg/kg at PRow during the dry season compared to control of 16.72 mg/kg at PW during the dry season to 30.87 mg/kg at PRow during the wet season. Controls were higher than study locations and surface was higher than subsurface chloride levels. Wet season levels were relatively higher than levels during the dry season. Chloride is a measure of salt content. The levels are low and is related to the generally low mineralization as seen in low conductivity values. This is good for the soils.

Exchangeable Cations and Heavy metals:

Results of measurements for exchangeable cations and heavy metals are presented in Table 4.7c & d for the Proposed Wells and Pipeline Right of Way locations respectively. Detailed results at found in Appendix 4.6.5.2 a&b for wet and dry seasons respectively.

Exchangeable Cations: Mean cation (Na, K, Ca and Mg) contents in the wet season at the proposed well site were 20.61 cmol/kg, 8.63 cmol/kg, 11.38 cmol/kg, and 7.65 cmol/kg respectively in surface (0 – 15 cm) soil while the corresponding values for the subsurface (15 – 30 cm) soil layer were 19.9 cmol/kg, 7.59 cmol/kg, 13.49 cmol/kg and 7.09 cmol/kg respectively. In the dry season, mean values of exchangeable cations were 23.22 cmol/kg (Na), 8.6 cmol/kg (K), 10.65 cmol/kg (Ca) and 7.07 cmol/kg (Mg) in the surface soil and 21.25 cmol/kg, 6.97 cmol/kg, 12.51 cmol/kg and 4.88 cmol/kg respectively in the sub-surface soil. In both seasons and at both soil depths, exchangeable cations were higher than the critical levels in soils.

At the pipeline RoW, exchangeable cations in surface (0 – 15) soil during the wet season were 25.24 cmol/kg, 7.72 cmol/kg, 10.27 cmol/kg and 7.15 cmol/kg for Na, K, Ca and Mg respectively. The corresponding values for the sub-surface soil were 19.9 cmol/kg, 7.59 cmol/kg, 13.49 cmol/kg, and 7.09 cmol/kg. During the dry season cation contents of 23.22 cmol/kg (Na), 8.6 cmol/kg (K), 10.65 cmol/kg (Ca) and 7.07 cmol/kg (Mg) at the 0 – 15cm soil depth and 21.25 cmol/kg, 6.97 cmol/kg, 12.51 cmol/kg and 4.88 cmol/kg for Na, K, Ca and Mg respectively at the sub-surface (15 – 30 cm) depth were obtained. The soils are therefore well supplied with exchangeable cations and can support crop production. Calcium is a major nutrient cation. Levels of 45 ppm are very low and 2500 ppm high. NSW (2004) recommends levels >5 meq/100g (>5 cmol/kg), magnesium >1.6 cmol/kg, potassium > 0.5 cmol/kg and sodium <1.0 cmol/kg. All measured cations are adequate for good soils but sodium was high compared to recommended levels.

Heavy metals

Iron: At the proposed Wells (PW) location, iron ranged from 1723 mg/kg during the wet season to 1945 mg/kg during the dry season compared to control of 1905 mg/kg during the wet to 2022 mg/kg during the dry season at the surface levels. At the subsurface level, Fe ranged from 1510 mg/kg during the wet to 1887 mg/kg during the dry compared to control of 1877 mg/kg during the wet to 2015 mg/kg during the dry season.

Along the proposed Pipeline Right of Way (PRoW), iron ranged from 2035mg/kg during the dry season to 2158 mg/kg during the wet season compared to control of 1905 mg/kg during the wet to 2015 mg/kg during the dry season at the surface levels. At the subsurface level, Fe ranged from 1873 mg/kg during the wet to 2015 mg/kg during the dry compared to control of 1877 mg/kg during the wet to 2022 mg/kg during the dry season. According to Apps (2016) levels of 40 ppm is low while 500 ppm is too high. All values were higher than the recommended level for good soils. However, iron occurs widely in Niger Delta soils and does not constitute an environmental hazard.

Copper: At PW, Copper ranged from 1.83 mg/kg during the dry season to 2.4 mg/kg during the wet season compared to control of 1.36 mg/kg during the dry season to 2.09 mg/kg during the wet season at the surface levels. At the subsurface levels, Cu ranged from 1.47 mg/kg during the dry to 2.17 mg/kg during the wet compared to control of 2.64 mg/kg during the dry to 2.85 mg/kg during the wet seasons.

Along the proposed Pipeline Right of Way (PRoW), copper ranged from 1.51mg/kg during the dry season to 1.86 mg/kg during the wet season compared to control of 1.82 mg/kg during the dry to 2.09 mg/kg during the wet season at the surface levels. At the subsurface level, Cu ranged from 1.53 mg/kg during the wet to 1.82 mg/kg during the dry compared to control of 1.36 mg/kg during the dry to 2.85 mg/kg during the dry season. Irrespective of the soil depth or season, mean copper of the soil was above the critical level of 1.00 mg/kg. For good quality soils copper should be 2-50 ppm (NSW, 2004)

Zinc: At PW, Zinc ranged from 37.69 mg/kg during the dry season to 62.12 mg/kg during the wet season compared to control of 22.57 mg/kg during the dry season to 52.92 mg/kg during the wet season at the surface levels. At the subsurface levels, Zn ranged from 32.25 mg/kg during the dry to 57.73 mg/kg during the wet compared to control of 28.51 mg/kg during the dry to 71.23 mg/kg during the wet seasons.

Along the proposed Pipeline Right of Way (PRoW), zinc ranged from 32.19 mg/kg during the dry season to 48.93 mg/kg during the wet season compared to control of 28.51 mg/kg during the dry to 52.92 mg/kg during the wet season at the surface levels. At the subsurface level, Zn ranged from 28.51 mg/kg during the dry to 37.6 mg/kg during the wet compared to control of 22.57 mg/kg during the dry to 71.25 mg/kg during the wet season. Zinc contents of the soils in both seasons were below the critical levels of 250 mg/kg. For good soils zinc should be 1-200 ppm (NSW, 2004). According to Apps (2004), 2 ppm is low and 10 ppm is high.

Lead: At PW, Lead ranged from 2.07 mg/kg during the dry season to 2.48 mg/kg during the wet season compared to control of 2.09 mg/kg during the wet season to 4.80 mg/kg during the dry season at the surface levels. At the subsurface levels, Pb ranged from 1.84 mg/kg during the dry

to 2.29 mg/kg during the wet compared to control of 2.64 mg/kg during the dry to 2.85 mg/kg during the wet seasons.

Along the proposed Pipeline Right of Way (PRoW), lead ranged from 1.65 mg/kg during the dry season to 2.16 mg/kg during the wet season compared to control of 2.09 mg/kg during the wet to 2.65 mg/kg during the dry season at the surface levels. At the subsurface level, Pb ranged from 2.03 mg/kg during the wet to 2.65 mg/kg during the dry compared to control of 2.85 mg/kg during the wet to 4.81 mg/kg during the dry season. For good soils lead should be <35 ppm (NSW, 2004)

Cadmium: At PW, Cadmium ranged from 0.06 mg/kg during the wet season to 0.066 mg/kg during the dry season compared to control of 0.05 mg/kg during the wet season to 0.057 mg/kg during the dry season at the surface levels. At the subsurface levels, Cd ranged from 0.05 mg/kg during the wet to 0.06 mg/kg during the dry compared to control of 0.06 mg/kg during the dry to 0.07 mg/kg during the wet seasons.

Along the proposed Pipeline Right of Way (PRoW), cadmium ranged from 0.05 mg/kg during the wet season to 0.06 mg/kg during the dry season compared to control of 0.05 mg/kg during the wet to 0.07 mg/kg during the dry season at the surface levels. At the subsurface level, Cd ranged from 0.04 mg/kg during the wet to 0.07 mg/kg during the dry compared to control of 0.06 mg/kg during the dry to 0.07 mg/kg during the wet season. For good soils cadmium should be <1ppm (NSW, 2004)

Nickel: At PW, Nickel ranged from 3.46 mg/kg during the dry season to 4.25 mg/kg during the wet season compared to control of 3.21 mg/kg during the wet season to 7.32 mg/kg during the dry season at the surface levels. At the subsurface levels, Ni ranged from 3.97 mg/kg during the dry to 4.49 mg/kg during the wet compared to control of 4.04 mg/kg during the dry to 4.37 mg/kg during the wet seasons.

Along the proposed Pipeline Right of Way (PRoW), nickel ranged from 3.16 mg/kg during the dry season to 3.74 mg/kg during the wet season compared to control of 3.21 mg/kg during the wet to 4.04 mg/kg during the dry season at the surface levels. At the subsurface level, Ni ranged from 3.87 mg/kg during the wet to 4.04 mg/kg during the dry compared to control of 3.16 mg/kg during the wet to 7.33 mg/kg during the dry season. For good soil nickel should be 1-20 ppm (NSW, 2004)

Chromium: At PW, Chromium ranged from 0.25 mg/kg during the dry season to 0.28 mg/kg during the wet season compared to control of 0.24 mg/kg during the wet season to 0.43 mg/kg during the dry season at the surface levels. At the levels, Cr ranged from 0.22 mg/kg during the dry to 0.26 mg/kg during the wet compared to control of 0.33 mg/kg during the wet to 0.49 mg/kg during the dry seasons.

Along the proposed Pipeline Right of Way (PRoW), chromium ranged from 0.21 mg/kg during the dry season to 0.26 mg/kg during the wet season compared to control of 0.24 mg/kg during the wet to 0.49 mg/kg during the dry season at the surface levels. At the subsurface level, Cr ranged from 0.23 mg/kg during the wet to 0.49 mg/kg during the dry compared to control of 0.33 mg/kg during the wet to 0.44 mg/kg during the dry season.

Arsenic: At PW, Arsenic ranged from 0.01 mg/kg during the wet season to 0.02 mg/kg during the dry season compared to control of 0.01 mg/kg during the wet season to 0.014 mg/kg during the dry season at the surface levels. At the subsurface levels, As ranged from 0.01 mg/kg during the wet to 0.019 mg/kg during the dry compared to control of 0.01 mg/kg during the wet to 0.02 mg/kg during the dry seasons.

Along the proposed Pipeline Right of Way (PRoW), arsenic ranged from 0.01 mg/kg during the wet season to 0.02 mg/kg during the dry season compared to control of 0.01 mg/kg during the wet to 0.02 mg/kg during the dry season at the surface levels. At the subsurface level, As ranged from 0.01 mg/kg during the wet to 0.02 mg/kg during the dry compared to control of 0.01 mg/kg during the wet and dry season. For good quality soil arsenic should be less than 20pm (NSW, 2004)

Table 4.7c: Summary results of Exchangeable cations and Heavy metals in soils around the Proposed Wells in the study area

Soil Properties	Proposed Wells							
	Wet Season				Dry Season			
	0 - 15	Control	15-30	Control	0-15	Control	15-30	Control
Na (cmol/kg)	20.61±7.3	21.8±8.6	19.9±8.5	20.23±in4	23.22±8.4	27.67±2.2	21.25±9.8	28.05±2.7
K (cmol/kg)	8.63±3.2	7.38±1.4	7.59±1.9	10.66±1.2	8.6±4	8.85±0.4	6.97±2.4	9.77±0.4
Ca (cmol/kg)	11.38±6.7	11.92±4.8	13.49±6.7	15.24±2.7	10.65±6.8	9.06±1.2	12.51±6.4	8.6±3.3
Mg (cmol/kg)	7.65±5.4	6.48±4.3	7.09±5.8	8.81±6.9	7.07±4.6	12.56±3.6	4.88±4.4	11.18±9.8
Fe (mg/kg)	1723.37±725.89	1905.52±146.71	1510.85±723.75	1877.67±267.75	1945.1±606.08	2022.445±777.81	1887.097±641.22	2015.873±694.16
Cu (mg/kg)	2.4±1.79	2.09±1.41	2.17±1.94	2.85±2.25	1.831±1.28	1.364±1.04	1.47±1.33	1.823±0.27
Zn (mg/kg)	62.12±42.15	52.92±34.01	57.73±45.4	71.25±54.31	37.699±19.06	22.575±3.59	32.254±19.82	28.513±12.05
Pb (mg/kg)	2.48±1.75	2.09±1.41	2.29±1.88	2.85±2.25	2.072±1.43	4.806±0.39	1.842±1.61	2.647±2.2
Cd (mg/kg)	0.06±0.04	0.05±0.03	0.05±0.04	0.07±0.05	0.066±0.03	0.057±0.02	0.06±0.03	0.065±0.01
Ni (mg/kg)	4.25±1.93	3.21±2.15	4.49±2.46	4.37±3.43	3.455±1.69	7.328±0.6	3.79±2.01	4.041±3.35
Cr (mg/kg)	0.28±0.2	0.24±0.16	0.26±0.21	0.33±0.26	0.259±0.17	0.439±0.36	0.224±0.17	0.491±0.13
As (mg/kg)	0.01±0	0.01±0	0.01±0	0.01±0	0.02±0.01	0.014±0	0.019±0.01	0.022±0.02

Source: Enwhe Field Data for Wet Season (September) and Dry season (November), 2016

Table 4.7d: Summary results of Exchangeable cations and Heavy metals in soils along the Pipeline Right of Way in the study area

Soil Properties	Pipeline Right of Way							
	Wet Season				Dry Season			
	0 -15	control	15 - 30	control	0 -15	control	15 - 30	control
Na (cmol/kg)	25.24±8.2	21.8±8.6	25.32±9.3	20.23±4	23.22±8.4	27.67±2.2	21.25±9.8	28.05±2.7
K (cmol/kg)	7.72±2.5	7.38±1.4	7.32±1.8	10.66±1.2	8.6±4	8.85±0.4	6.97±2.4	9.77±0.4
Ca (cmol/kg)	10.27±6.6	11.92±4.8	10.57±5.5	15.24±2.7	10.65±6.8	9.06±1.2	12.51±6.4	8.6±3.3

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Soil Properties	Pipeline Right of Way							
	Wet Season				Dry Season			
	0 -15	control	15 - 30	control	0 -15	control	15 - 30	control
Mg (cmol/kg)	7.15±5.4	6.48±4.3	6.16±5	8.81±6.9	7.07±4.6	12.56±3.6	4.88±4.4	11.18±9.8
Fe (mg/kg)	2158.7±897.8 1	1905.52±146.7 1	1873.35±776.6 6	1877.67±267.7 5	2035.3±640.6 6	2015.87±694.1 6	2015.87±694.1 6	2022.45±777.81
Cu (mg/kg)	1.86±1.33	2.09±1.41	1.53±1.28	2.85±2.25	1.51±0.94	1.82±0.27	1.82±0.27	1.36±1.04
Zn (mg/kg)	48.93±36.98	52.92±34.01	37.6±32.37	71.25±54.31	32.19±17.87	28.51±12.05	28.51±12.05	22.57±3.59
Pb (mg/kg)	2.16±1.65	2.09±1.41	2.03±1.74	2.85±2.25	1.65±1.19	2.65±2.2	2.65±2.2	4.81±0.39
Cd (mg/kg)	0.05±0.03	0.05±0.03	0.04±0.03	0.07±0.05	0.06±0.03	0.07±0.01	0.07±0.01	0.06±0.02
Ni (mg/kg)	3.74±2.24	3.21±2.15	3.87±2.17	4.37±3.43	3.16±1.5	4.04±3.35	4.04±3.35	7.33±0.6
Cr (mg/kg)	0.26±0.2	0.24±0.16	0.23±0.19	0.33±0.26	0.21±0.15	0.49±0.13	0.49±0.13	0.44±0.36
As (mg/kg)	0.01±0	0.01±0	0.01±0	0.01±0	0.02±0.01	0.02±0.02	0.02±0.02	0.01±0

Source: Enwhe Field Data for Wet Season (September) and Dry season (November), 2016

Aliphatic and Aromatic Hydrocarbons

Detailed results of aliphatic hydrocarbons, polycyclic aromatic hydrocarbons and Benzene, Toluene, Ethyl-benzene and Xylenes (BTEX) in soils of the study area are presented in Appendix 4.6.5.3 a & b for the wet and dry seasons respectively. Summary of results of hydrocarbon measurements in soils of the study area is presented in Table 4.7e.

Table 4.7e: Summary results of Aliphatic and Polycyclic Aromatic Hydrocarbon measurement in soils of the study area

Parameters	Wet season				Dry Season			
	Mean	Min	Max	STD	Mean	Min	Max	STD
Aliphatics (nC8 - nC44)	0.0574	0.002	0.664	0.0954	0.0097	<0.001	0.148	0.0175
Naphthalene	0.0005	<0.001	0.019	0.0022	0.0006	<0.001	0.009	0.0017
Acenaphthalene	0.0042	<0.001	0.274	0.0245	0.0007	<0.001	0.009	0.0021
Acenaphthene	0.0079	<0.001	0.134	0.0190	0.0021	<0.001	0.009	0.0026
Florene	0.0065	<0.001	0.122	0.0159	0.0012	<0.001	0.008	0.0017
Phenathrene	0.0035	<0.001	0.059	0.0086	0.0010	<0.001	0.008	0.0018
Anthracene	0.0083	<0.001	0.264	0.0317	0.0004	<0.001	0.01	0.0015
Fluoranthene	0.0014	<0.001	0.049	0.0052	0.0003	<0.001	0.01	0.0013
Pyrene	0.0021	<0.001	0.053	0.0062	0.0002	<0.001	0.007	0.0011
Benzo(a)anthracene	0.0034	<0.001	0.084	0.0099	0.0001	<0.001	0.009	0.0009
Crysene	0.0045	<0.001	0.088	0.0152	0.0007	<0.001	0.006	0.0016
Benzo(b)fluoranthrene	0.0002	<0.001	0.021	0.0018	<0.001	<0.001	<0.001	0
Benzo(a)pyrene	0.0006	<0.001	0.026	0.0034	<0.001	<0.001	<0.001	0
Benzo(k)fluoranthrene	0.0001	<0.001	0.017	0.0015	<0.001	<0.001	<0.001	0
Indeno(1,2,3) perylene	0.0001	<0.001	0.008	0.0007	<0.001	<0.001	<0.001	0
Dibenzo(a,h)anthracene	<0.001	<0.001	0.006	0.0005	<0.001	<0.001	<0.001	0
Benzo(g,h,i) perylene	<0.001	<0.001	<0.001	0	<0.001	<0.001	<0.001	0

Source :Enwhe Field Data for Wet Season (September) and Dry season (November) , 2016

Aliphatic Hydrocarbons

Levels of aliphatic hydrocarbons ranged from below the detection limit (<0.001 mg/kg) in the dry season to 0.664 mg/kg during the wet season with no significant difference between the surface level and bottom levels. There was also no significant difference between study locations and control. Values were generally low at all study locations and well below levels of hydrocarbons known to be of environmental concern.

Polycyclic Aromatic Hydrocarbons (PAH)

PAH ranged from below detection limit at most locations during the wet and dry seasons to a maximum of 0.274 mg/kg recorded for Acenaphthalene in the wet season. Wet season levels were significantly higher than dry season concentrations at all study locations. During the wet season, six (6) PAH congeners were undetectable in the soil (Benzo(b)fluoranthrene, Benzo(a)pyrene, Benzo(k)fluoranthrene, Indeno(1,2,3) perylene, Dibenz(a,h)anthracene, Benzo(g,h,i) perylene). Apart from dibenz(a,h) anthracene and benzo (g,h,i) perylene which were not encountered in any of the samples, all other PAH congeners were detected during the wet season. The wide distribution of both the 3-4 ring polycyclics and the higher ring polycyclics is an indication of the mixed sources of hydrocarbons (petrogenic and pyrogenic) particularly during the wet season in the study area. Levels of PAH were generally low and below levels of concern in soils.

Benzene, Toluene, Ethylbenzene and Xylenes (BTEX)

BTEX were not detected in the soils of the study area indicating the absence of any recent inputs of petroleum hydrocarbons.

Soil Microbiology

Detailed results of microbiological studies in the soils of the study area are presented in Appendix 4.6.5.4. The summary of results for the proposed wells area is presented in Table 4.7f.

Total heterotrophic bacteria (THB)

At the surface soil, Total heterotrophic bacteria (THB) count varied from 3.53×10^4 cfu/g during the wet season to 3.54×10^4 cfu/g during the dry season compared to control of 4.1×10^4 cfu/g. At the subsurface, THB ranged from 2.48×10^4 cfu/g during the dry season to 2.77cfu/g during the wet season compared to control of 3.05×10^4 cfu/g. There was no significant difference between levels in the wet and dry seasons and between study locations and control.

Hydrocarbon Utilizing Bacteria (HUB)

At the surface soils, HUB ranged from 0.50×10^3 cfu/g during the wet season to 0.51×10^3 cfu/g during the dry season compared to control of 0.4×10^3 cfu/g. At the subsurface level, HUB ranged from 0.38×10^3 cfu/g during the dry season to 0.50×10^3 cfu/g during the wet season compared to control of 0.39×10^3 cfu/g. There was no significant difference between levels in the wet and dry seasons and between study locations and control.

Similar variations were observed in the counts of Total Heterotrophic Fungi (THF) and Hydrocarbon Utilizing Fungi (HUF). The ratio of HUB to THB which is commonly used as indicator of petroleum pollution were markedly lower than the threshold of 10% at all locations indicating absence of petroleum pollution in the soils.

Table 4.7f: Microbial properties in the wet season in proposed well area

	Wet Season				Dry Season	
	0 - 15	control	15 - 30	Control	0 - 15	15 - 30
(THB) x 10 ⁴ (cfu/g)	3.53±2.6	4.1±1.98	2.775±2.32	3.05±0.07	3.54±1.42	2.48±1.5
(THF) x 10 ³ (cfu/g)	0.505±0.31	0.4±0.28	0.543±0.44	0.6±0.42	0.67±0.42	0.55±0.18
(HUB) x 10 ³ (cfu/g)	0.505±0.5	0.35±0.07	0.505±0.51	0.39±0.13	0.51±0.25	0.38±0.19
(HUF) x 10 ² (cfu/g)	0.044±0.02	0.03±0.01	0.053±0.05	0.04±0.03	0.08±0.02	0.05±0.04

4.7.6: Land use and Land cover

The land use /Land cover characteristics and percentage change over three periods (1988, 1999 and 2015) in Gbaran area are presented in Table 4.8. The land use types are:

- Water:** The area occupied by water remained approximately the same across the three periods. It covered an area of 3.15 km² in 1988, 3.92 km² in 1999 and 3.74 km² in 2015. The little changes in area coverage can be ascribed to some areas that are seasonally flooded.
- Primary forest:** The primary forest area decreased across the three periods. It covered an area of 61.8 km² in 1988 and decreased to 56.6km² in 1999 which decreased further to 47.52km² in 2015. This decrease is due to the conversion of the primary forest into fallow lands and built- up around the study area.
- Fallow Lands:** The fallow lands increased across the three periods. It covered an area of 2.53km² in 1988 and increased to 6.05 km² in 1999 and further increased to 9.51km² in 2015. The increase in the land coverage is due to the deforestation of the primary forest into fallows because of increase in urbanisation and other developmental activities.
- Urban/Industrial/Bare Lands:** Urban/Industrial/Bare Land class increased across the three periods. This class covered an area of 1.07 km² in 1988, increased to 1.98 km² in 1999 and increased further to 5.21 km² in 2015. This growth is observed around Obunaghan, Tombia, Gbarantoru and the SPDC CPF area. This is an indication of high urban development/construction and influx of people into the study area.

Table 4.8 Land cover in kilometer square for three (3) years (Source: time lapse and Normalised differential vegetation index analysis of landsat satellite imageries of the study area)

Land cover Types	Year 1988	Year 1999	Year 2015
Water(km ²)	3.15	3.92	3.74
Primary Forest(km ²)	61.8	56.6	47.52
Fallow Vegetation(km ²)	2.53	6.05	9.51
Urban/Industrial/Bare Land(km ²)	1.07	1.98	5.21
Soil(km ²)	Nil	Nil	2.57
Total	68.55	68.55	68.55

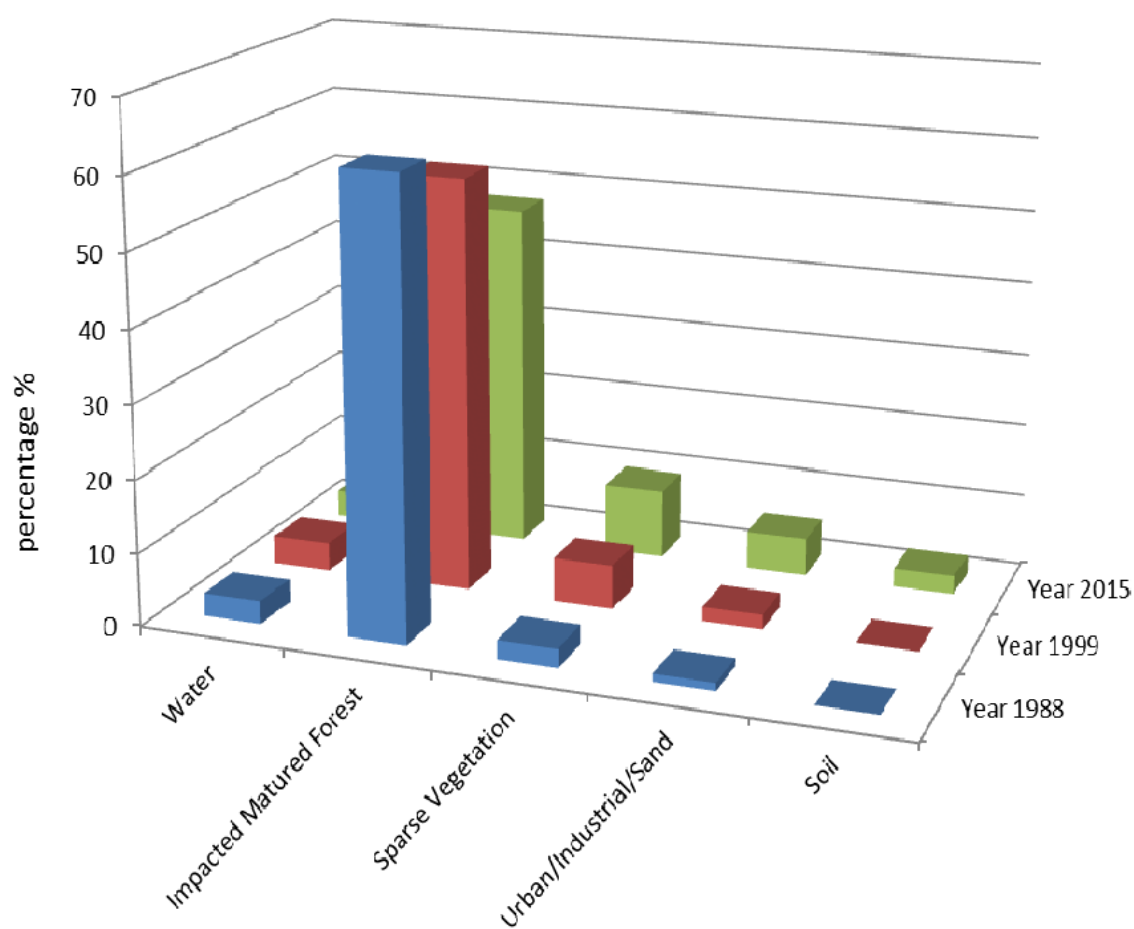


Fig 4.3: Percentage pictorial representation of Land cover changes in 1988, 1999 and 2015 (Source: time lapse and Normalised differential vegetation index analysis of satellite imageries in the study area)

4.7.7: Geology

Regional Geology

The study area is situated within the Niger Delta sedimentary Basin. The Niger Delta depositional complex covers the Cenozoic Formation of the Abakaliki Trough in Eastern Nigeria to the Benin Flank in the West and the Atlantic Ocean shelf in the South (Ofoegbu, 1998). The Niger Basin was formed in the Tertiary from an interplay of subsidence and deposition as a result of successive transgressions and regressions of the sea (Hosper, 1965). This resulted in the deposition of three lithostratigraphic units in the Niger Delta. These are the Akata, Agbada, and Benin Formations with overall sediment thickness of about 10,000 metres. The Akata Formation (Paleocene) is the oldest and consists of plastic, low density, under compacted, high pressured, shallow marine to deep water clays, shales and limestones with approximate thickness of 1000 metres. The Akata Formation is the dominant petroleum source rock in the Niger Delta. The Agbada Formation which overlies the Akata Formation consists up of alternation of marine shale and sandstones with an overall thickness of 3000 metres and is the petroleum reservoir rock in the Niger Delta. The youngest unit is the Benin Formation, dominated by Coastal Plain Sands which is made up of coarse sands with occasional clay/clayey intercalations. The Benin Formation is the most prolific aquifer system in the Niger Delta Basin. This Formation generally does not exceed 120 meters in thickness is predominantly unconfined (Amangabara and Ejenma, 2009). The hydraulic conductivities of the sands of the Benin Formation vary from 3.8×10^{-3} to 9.0×10^{-2} cm/sec, indicative of a productive aquifer specific capacities ranging from 6700 lit/hr/m to 13,500 lit/hr/m (Offodile, 1991).

Hydrogeology

The study area is located within the Orashi/Nun River flood plains, characterized by low lying perennial or seasonally flooded areas. The area slopes imperceptibly in the south direction towards the River Niger and is drained by a network of adjoining creeks and marshes. Thirteen (13) ground water monitoring boreholes including two (2) controls were drilled to obtain geologic and hydrogeologic data of the area. The stratigraphic units from the superficial layer to the aquifer level, and aquifer type were determined *in-situ* at the time of coring. Drill cores were sampled at intervals of 1m for stratigraphic analysis. The depth of water levels of all the boreholes was obtained using an electronic dip meter. Each monitoring borehole was gravel packed, flushed, cased with 4 inch Polyvinyl Chloride pipe and allowed to attain equilibrium. Thereafter, the depths of water levels of each of the boreholes were obtained using an electronic dip meter. Coring and groundwater samples were collected in appropriately labeled containers, and preserved for subsequent laboratory analysis of the physicochemical and microbial characteristics.

Stratigraphic and Aquifer Characteristics

The stratigraphy of the near surface geology as inferred from the bore-hole information. The lithologic profiles of boreholes at Enwhe Field in presented in Fig. 4.4a. The stratigraphy is generally defined by a dark brownish woody humic loam material at the surface. The clay content of the lithology increases from about one meter (1m) from the surface level down to a depth of six

to seven meters (6-7m). This clay material overlies a sandy material that is about three to four meters (3-4m) thick that become coarser with increasing depth until the first water-bearing lithology (aquifer) is encountered. Some locations within the study area are characterized with a lithostratigraphy consisting of a dark brownish humic loam material at the surface with a clay content that increases from the surficial layer down to a depth of about four meters (4m) and overlies a poorly sorted sandy-clay material of approximately three meters (3m) thick. Underlying this sandy-clay material is a medium grained sand that goes down to about ten meters (10m). The medium sandy materials become coarser with increasing depth, and join the aquifer at twelve meters (11-12m) depth. The water level measured in the boreholes ranges from 1.6 m in borehole 1 to 2.2 m in borehole 9. The aquifer of Enwhe Field area is pervious, and the ground water recharge is via percolation from precipitation, and surface water bodies. Consequently, the base flow of the surface water bodies influences the ground water recharge rate especially during the dry season when the water table level drops.

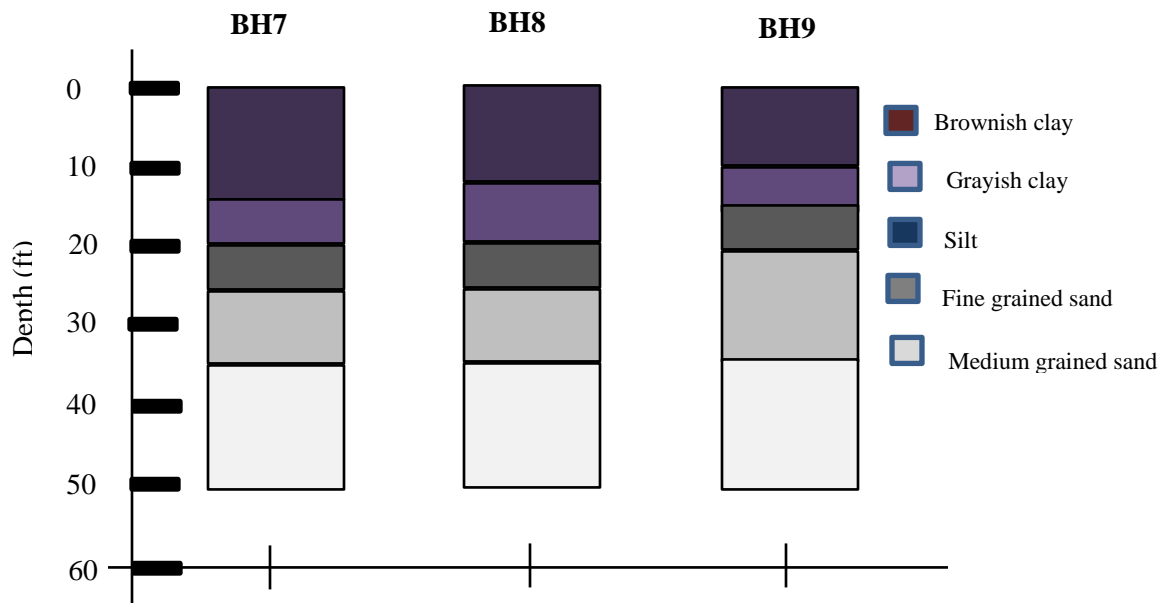


Fig. 4.4a: Lithologic profile of boreholes at Enwhe Field
Source: Field Data (2016)

Groundwater Flow Direction

The vertical change in groundwater elevation over horizontal distance in the direction of groundwater flow shows a gentle slope and can be used to determine the direction of groundwater movement (Abah, 2014). In this study Groundwater flow direction in the area was determined using the data from 3 boreholes located in a triangular manner around the proposed Wells (PW) area. The depth to water level in each borehole was measured with a measuring tape, while the elevation of the borehole points above mean sea level were measured with a GARMIN Global Positioning System (GPS). The depth to water level in each borehole was then subtracted from the

elevation of the borehole to obtain the hydraulic head of water at that point. A triangle was drawn on the map with the boreholes (and their respective total heads) at the apices. Equipotential lines were drawn, and perpendicular lines to the equipotential lines in the direction of lower heads gave the groundwater flow direction in the area. The data shows that the groundwater flow direction in the area is from North East to South West. This is in conformity with the regional groundwater flow direction in Niger Delta, which is from Northeast towards the coast in the south. Thus if there is any pollution of groundwater in the area, those south of the point of pollution are most likely to be affected.

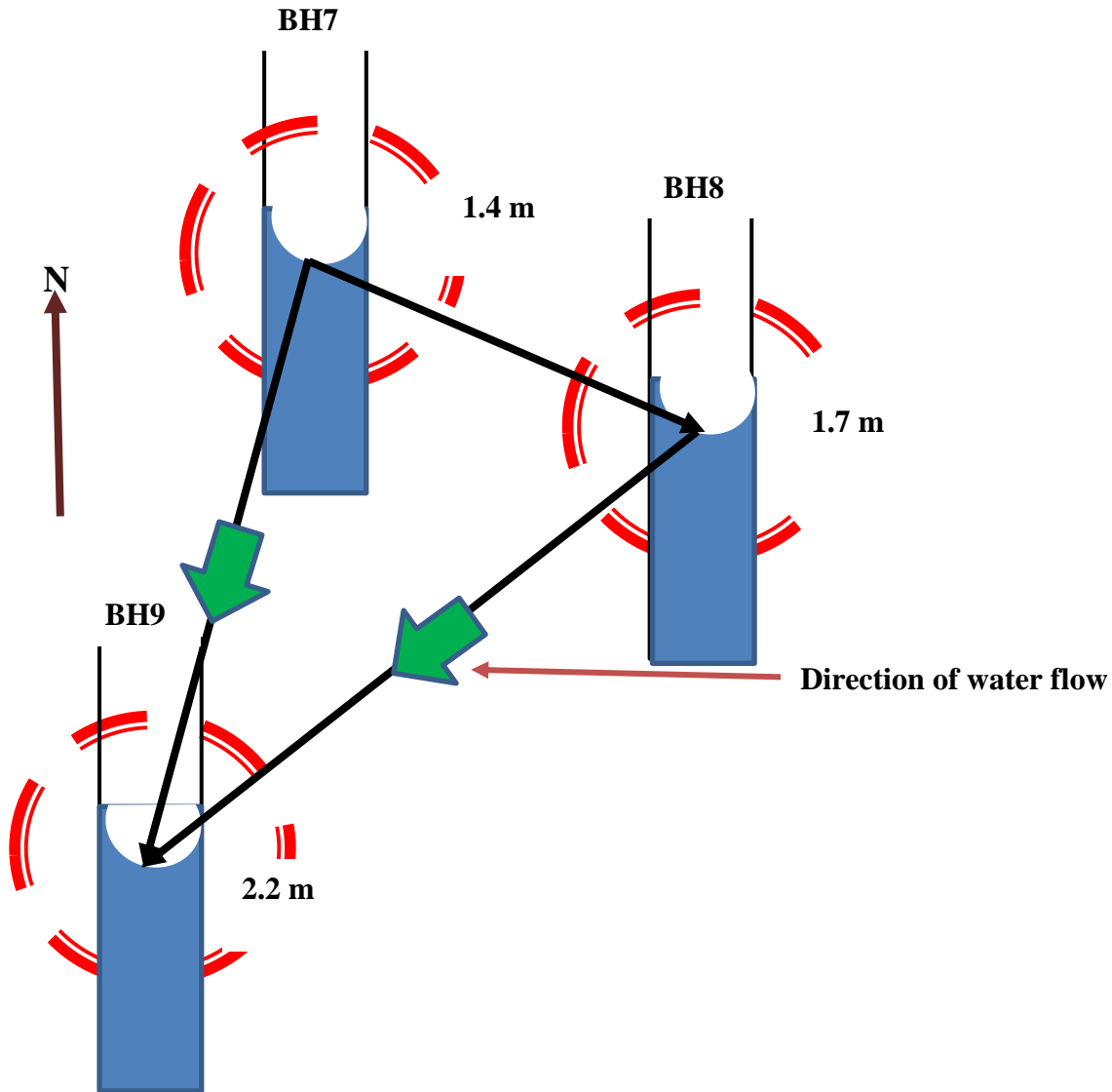


Fig. 4.4b: Water Levels of borehole in Enwhe Field
 Source: Field data (2016)

4.7.8 Ground Water Quality

Physicochemical studies

The summary of results of physicochemical measurements in Groundwater are presented in Table 4.9a for the wet and dry seasons. Detailed results are presented in Appendix 4.6.8a & b. All results are presented in relation to sampling strategy to cover the Proposed Wells (PW), Pipeline Right of Way (PRoW) and Existing Wells compared to control.

pH:

pH ranged from mean value of 5.52 at Proposed wells (PW) to 6.44 at Existing Wells (EW) compared to 6.44 at the control during the wet season and from 6.12 along Pipeline RoW (PRoW) to 6.50 at Existing Wells compared to control of 6.55. Dry season values were relatively higher than those of the wet season but there were no differences between study locations and control. Most values were mildly acidic and below the Nigerian Limits for drinking water of 6.5-8.5.

Temperature:

Borehole water temperature varied from a mean of 28.14°C at PW to 31.1°C at EW compared to control of 22.8°C during the wet season and from 27.28°C at PW to 30.1°C at EW compared to control of 27°C during the dry season. Nigerian standards recommend that drinking water be at ambient temperature. The water temperature are normal under ambient conditions in the study area.

Redox Potential

Redox potential of the ground water ranged from a mean of 56.03 mV at PRoW to 67.3 mV at PW compared to 12.1 mV at control during the wet season and from 33.48 mV at PW to 44.32 mV at PRoW compared to 33.6 mV at control during the dry season. Wet season values at study locations were higher than dry season values. Control was significantly lower than study locations during the wet season but all values were oxidizing showing the presence of sufficient oxygen to aid breakdown of organics.

Electrical Conductivity

Conductivity varied from a mean of 17.45 $\mu\text{S}/\text{cm}$ at PW to 312 $\mu\text{S}/\text{cm}$ at EW compared to control of 46.65 $\mu\text{S}/\text{cm}$ during the wet season and from 15 $\mu\text{S}/\text{cm}$ at EW to 43.21 $\mu\text{S}/\text{cm}$ at PW compared to 17 $\mu\text{S}/\text{cm}$ at the control during the dry season. Wet season values were higher than dry season values showing the importance of surface run-off inputs compared to dilution from rainfall. Nigerian drinking water standards puts a permissible limit of 1000 $\mu\text{S}/\text{cm}$. The measured conductivity values were within the permissible limits.

Turbidity, Total Suspended Solids and Color

Turbidity, Total Suspended Solids and Colour are closely related parameters with usually similar causes. Turbidity ranged from a mean value of 42,354 NTU at PRoW to 51,400 NTU at EW

compared to 38,590 NTU the control during the wet season and from 49 NTU at EW to 496 NTU at PRow compared to 39 NTU at the control. Nigerian drinking water Permissible limit is 5 NTU. All measurements were above the limit pointing to infiltration of surface materials into the boreholes. The studied boreholes tap the upper aquifer characterized by very high water tables and prone to surface infiltration.

Total Suspended Solids ranged from 48,501 mg/l at PW to 55,000 mg/l at EW compared to control of 49,500 mg/l during the wet season and from 33 mg/l at EW to 526 mg/l at PRow compared to 37 mg/l at the control during the dry season. TSS was significantly higher during the wet season than dry season showing the influence of rain-related run-off and infiltration of into the boreholes. The Nigerian Environmental Standards and Regulations Enforcement Agency (NESREA) recommends requires that drinking water be devoid of suspended solids.

Colour ranged from 35 units at PRow to 45 units at EW compared to control of 35.5 units at control during the wet season and from 10.63 units at PW to 19 units at EW compared to 13.5 units at the control during the dry season. Wet season values were significantly higher than dry season concentrations but with no clear spatial trend in relation to control. Nigerian drinking water standards recommends 15 units as Maximum permissible limit. Most samples particularly during the rainy season showed higher values indicating rain-related inputs as the major cause of high colour.

Total Dissolved Solids (TDS)

TDS varied from 7.84 mg/l at PW to 155 at EW compared to control of 23.35 mg/l during the wet season and from 7.50 mg/l at EW to 21.64 mg/l at PW compared to control of 8.75 mg/l during the dry season. TDS is a measure of salt concentration. Values were typical fresh water and are within the NIS permissible limit of 500 mg/l.

Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD)

BOD varied from 1.75 mg/l at PW to 3.20 mg/l at EW compared to 1.65 mg/l at the control during the wet season and from 1.2 mg/l at PW to 1.40 mg/l at EW compared to 1.1 mg/l at the control during the dry season. Wet season values were higher than dry season concentrations with no significant difference with control. NIS recommends a limit of 5 mg/l for drinking water. All measurements are within the stated limits.

COD varied from 5.36 mg/l at EW to 8.58 mg/l at PRow compared to control of 7.83 mg/l during the wet season and from 9.13 mg/l at PW to 14.55 mg/l at EW compared with 9.09 mg/l at the control during the dry season. NIS recommends a limit of 15 mg/l for drinking water. Measured values are within the stated limit indicating that the ground waters are not polluted by organic matter.

Dissolved Oxygen (DO)

DO varied from 0.3 mg/l at EW to 3.48 mg/l at PW compared to 2,7 mg/l at the control during the wet season and from 4.63 mg/l at PW to 5.6 mg/l at EW compared to control of 4.70 mg/l during the dry season. Low DO levels are normal in ground water (Fondriest Environmental Inc (2013)). Considering the low BOD and COD values, the low DO does not indicate organic pollution.

Salinity as Chloride

Chloride varied from 3.69 mg/l at PW to 74.15 mg/l at EW compared to 5.85 mg/l at controls during the wet season and from 3.28 mg/l at EW to 9.04 mg/l at PW compared to 4.77 mg/l at control during the dry season. Chloride values are typical of fresh water and are within WHO drinking water limits of 250 mg/l.

Table 4.9a: Summary results of Physicochemical measurements in boreholes around Enwhe Field during the wet season

Parameters	Wet Season				Dry Season				WHO Limits
	Proposed wells	Pipeline RoW	Existing wells	Control	Proposed wells	Pipeline RoW	Existing wells	Control	
	Mean±Std	Mean±Std	BH6	Mean±Std	Mean±Std	Mean±Std	BH6	Mean±Std	
pH	5.52±0.59	5.7±0.53	6.00	6.44±0.18	6.21±0.66	6.12±0.52	6.50	6.55±0.07	6.5 – 8.5
Temp°C	28.14±1.55	28.41±1.89	31.10	22.8±3.82	27.28±2.69	27.97±3.18	30.10	27±0.42	
Redox Potential mV	67.3±31.19	56.03±22.8	34.60	12.1±2.26	33.48±28.32	44.32±10.28	35.80	33.6±3.11	
Electrical Conductivity µS/cm	17.45±5.39	61.95±110.94	312.00	46.65±9.12	43.21±46.57	24.2±16.54	15.00	17±1.7	1000
Turbidity NTU	42958.75±26033	42354.51±32322	51400.0	38590.75±54460	59±50.44	496.85±991.6	49.1	39.85±20.58	10
TSS mg/L	48501±49321	53701.14±50529	55000.0	49500±36062	60.13±52.05	526.83±1070.21	33.0	37.5±7.78	0.00
TDS mg/L	7.84±0.94	30.96±55.39	155.80	23.35±4.6	21.64±23.3	12.12±8.26	7.50	8.75±1.2	500
THC mg/L	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	
COD mg/L	8.38±0.95	8.58±2.36	5.36	7.83±1.98	9.13±2.61	10.8±2.75	14.55	9.09±0.93	15.0
DO mg/L	3.48±1.88	3±2.72	0.30	2.7±1.13	4.63±0.54	4.8±0.61	5.60	4.7±0.42	4.00
BOD ₅ mg/L	1.75±0.59	2.34±0.62	3.20	1.65±0.92	1.2±0.46	1.28±0.48	1.40	1.1±0.42	5.00
Salinity as Cl mg/L	3.69±1.69	13.84±26.66	74.15	5.85±0.23	9.04±14.25	3.97±1.4	3.28	4.77±1.12	350
Nitrite mg/L	0.05±0.03	0.04±0.03	0.014	0.04±0.01	0.01±0	0.01±0.02	0.001	<0.001	
Colour mg/L	43.88±23.62	35.29±13.3	45	35.5±4.95	10.63±3.16	10.83±5.56	19	13.5±2.12	15.0
Alkalinity mg/L	16.88±5.99	18.76±7.03	23.70	26.2±4.53	20.21±7.86	16.95±4.48	20.60	23.65±3.75	
Oil & Grease mg/L	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.003
Nitrate mg/L	0.65±0.93	1.09±1.96	0.090	2.87±3.83	0.01±0	0.06±0.11	0.018	0.01±0	50.0
Phenols mg/L	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.001
Sulphate mg/L	3.17±3.49	12.62±27.44	74.82	5.32±4.03	2.27±2.36	1.9±0.86	2.41	0.58±0.24	100

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Parameters	Wet Season				Dry Season				WHO Limit s
	Proposed wells	Pipeline RoW	Existing wells	Control	Proposed wells	Pipeline RoW	Existing wells	Control	
	Mean±Std	Mean±Std	BH6	Mean±Std	Mean±Std	Mean±Std	BH6	Mean±Std	
Ammonia mg/L	5.6±6.69	6.11±7.08	4.069	1.45±0.03	0.08±0.01	0.14±0.14	0.056	#DIV/0!	1.50
Phosphate mg/L	0.12±0.16	0.76±1.81	0.026	0.16±0.19	0.02±0.02	0.03±0.02	0.013	0.03±0	3.50
reactive silica mg/L	2.31±1.23	2.61±1.23	3.71	3.11±0.17	0.24±0.08	0.28±0.09	0.36	0.16±0.04	

Alkalinity

Alkalinity varied from 16.88 mg/kg at PW to 23.70 mg/l at EW compared to 26.2 mg/l at the control during the rainy season and from 16.95 mg/l at PRow to 20.21 mg/l at PW compared to control of 23.65 mg/l in the dry season.

Nitrate

Nitrate varied between 0.09 mg/l at EW and 1.09 mg/l at PRow during the wet season and between 0.01 mg/l at PW and 0.06 mg/l at PRow during the dry season. All measurements were lower than the WHO limit of 50 mg/l for drinking water.

Sulphate

Sulphate ranged from 3.17 mg/l at PW to 74.82 mg/l at EW compared to control of 5.32 mg/l during the wet season and from 1.9 mg/l at PRow to 2.41 mg/l at EW compared to control of 0.58 mg/l during the dry season. Sulphate levels were within the 100 mg/l WHO limit.

Ammonium

Ammonium ranged from 4.06 mg/l at EW to 6.11 mg/l at PRow compared to control of 1.45 mg/l during the wet season and from 0.08 mg/l at PW to 0.14 mg/l at PRow compared to undetectable levels in the control during the dry season. Ammonia levels were significantly higher during the wet season than dry season and most values were above the WHO limit of 1.5 mg/l showing the impact of rain-related infiltration into the surface aquifers.

Phosphate

Phosphate ranged from 0.02 mg/l at EW to 0.76 mg/l at PRow compared to 0.16 mg/l at the control during the wet season and from 0.013 mg/l at EW to 0.03 mg/l at PRow compared to control of 0.03 mg/l during the dry season. Wet season values were higher than those of the dry season indicating the effect of rain-related infiltration. All concentrations were lower than the WHO limit of 3.5 mg/l.

Phenols and Oil and Grease

Phenols and Oil and Grease were not detected in the ground water samples.

Cations and Heavy metals

The summary of results of cations and heavy metals measurements in Groundwater are presented in Tables 4.9b for the wet and dry seasons. Detailed results are presented in Appendix 4.6.8c & d. All results are presented in relation to sampling strategy to cover the Proposed Wells (PW), Pipeline Right of Way (PRow) and Existing Wells compared to control.

Sodium, Potassium, Calcium and Magnesium are major ions which contribute to salt content in water. Sodium ranged from 2.74 mg/l at PW to 56.39 mg/l at EW compared to control of 5.8 mg/l

during the wet season and from 1.57 mg/l at EW to 6.72 mg/l at PW compared to control of 2 mg/l in the dry season. Values during wet season were relatively higher than dry season possible related to infiltration of materials into the surface aquifers. All values were below the WHO permissible limit of 200 mg/l for drinking water.

Potassium ranged from 0.74 mg/l PW to 11.47 mg/l at EW compared to 2.40 mg/l at the control and from 0.63 mg/l at PRow to 1.4 mg/l at PW compared to control of 0.47 mg/l during the dry season. Wet season values were relatively higher than dry season concentrations. All values were within the WHO limit of 3.9 mg/l.

Calcium ranged from 0.24 mg/l at the PW to 4.36 at the EW compared to control of 0.75 mg/l during the wet season and from 0.34 mg/l at PRow to 0.69 mg/l at EW compared to control of 0.71 mg/l during the dry season. Wet season showed relatively higher values than the dry season but all concentrations were below the WHO limit of 150 mg/l.

Magnesium ranged from 0.21 mg/l at PW to 1.04 mg/l at EW compared to control of 0.83 mg/l during the wet season and from 0.22 mg/l at PRow to 0.41 mg/l at EW compared to 0.2 mg/l at the control during the dry season. Dry season results were relatively higher than those of the dry season. The concentrations were generally above the WHO limit of 0.2 mg/l.

Manganese concentration at all locations were low (0.01 mg/l) and below the WHO limit of 0.5 mg/l while iron ranged from 0.64 mg/l at PRow to 0.82 mg/l at EW compared to control of 0.69 mg/l during the wet season and from 0.48 mg/l at PW to 0.87 mg/l at the EW compared to control of 0.31 mg/l at the control during the dry season. Iron levels were generally higher than the WHO NESREA limit of 0.3 mg/l. High iron content is common in groundwaters from the Niger Delta. Ngah and Nwankwola (2013) observed that most water boreholes in the Niger Delta deliver water with iron in objectionable concentration. The high iron concentration were more prevalent in the boreholes drilled in Freshwater Swamps/ Backswamp/ Meander Belt region as well as the mangrove swamps and coastal ridges.

Zinc ranged from 0.14 mg/l at EW to 0.2 mg/l at PRow compared to control of 0.14 mg/l during the wet season and from 0.19 mg/l at PW to 0.22 mg/l at EW compared to 0.2 mg/l at the control during the dry season. Zinc concentrations were below the WHO limit of 3.0 mg/l and therefore of no environmental concern. Cadmium, Chromium, Nickel, Vanadium, Lead and Mercury were not detected in the groundwater samples in both seasons. The groundwater in the study area is not polluted by heavy metals.

Table 4.9b: Summary results of Metals measurements in boreholes around Enwhe Field during the wet season

Parameters	Wet Season				Dry Season				WHO limits
	Proposed wells	Pipeline RoW	Existing wells	Control	Proposed wells	Pipeline RoW	Existing wells	Control	
	Mean±Std	Mean±Std	BH6	Mean±Std	Mean±Std	Mean±Std	BH6	Mean±Std	
Na mg/L	2.74±0.92	10.56±20.31	56.396	5.8±0.05	6.72±8.88	2.36±0.97	1.57	2±0.58	200
K mg/L	0.74±0.21	2.27±4.07	11.473	2.4±0.79	1.4±1.63	0.63±0.25	0.886	0.47±0.18	3.9
Ca mg/L	0.24±0.23	0.9±1.55	4.356	0.75±0.24	0.37±0.35	0.34±0.2	0.693	0.71±0.02	150
Mg mg/L	0.21±0.14	0.37±0.31	1.036	0.83±0.02	0.27±0.34	0.22±0.22	0.406	0.2±0.06	0.2
Mn mg/L	0.01±0	0.01±0	0.011	0.01±0	0.01±0	0.01±0	0.006	0.01±0	
Fe mg/L	0.68±0.22	0.64±0.2	0.820	0.69±0.09	0.48±0.16	0.52±0.22	0.873	0.31±0.1	0.3
Cd mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.005
Cr mg/L	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.05
Ni mg/L	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.02
V mg/L	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	
Pb mg/L	0.01±0	0±0	0.002	<0.02	<0.001	<0.001	<0.001	<0.001	0.01
Zn mg/L	0.19±0.05	0.2±0.04	0.140	0.14±0.02	0.19±0.02	0.2±0.01	0.216	0.2±0.02	3.0
Hg mg/L	<0.02	<0.03	<0.04	<0.05	<0.02	<0.02	<0.02	<0.02	0.001

Source: Enwhe Field Development EIA Field Data September, 2016 (Wet season) and November, 2016 (Dry Season)

Groundwater Microbiology

The summary of results of microbiological measurements in Groundwater are presented in Table 4.9c for the wet and dry seasons. Detailed results are presented in Appendix 4.6.8e & f. All results are presented in relation to sampling strategy to cover the Proposed Wells (PW), Pipeline Right of Way (PRoW) and Existing Wells compared to control.

Total Heterotrophic Bacteria (THB)

THB ranged from 4.7×10^3 cfu/ml at EW to 5.4×10^3 cfu/ml at PRoW compared to undetectable levels at the control during the wet season and from 1.75×10^3 cfu/ml at PW to 2.54×10^3 cfu/ml at EW compared to 2.55×10^3 cfu/ml at control during the dry season. Wet season values were generally higher than those of the dry season except at the control with the opposite trend.

Hydrocarbon Utilizing Bacteria (HUB)

HUB ranged from 1.2×10^2 cfu/ml at EW to 1.41×10^2 cfu/ml at PW compared to undetectable levels at the control during the wet season and from 1.18×10^2 cfu/ml at EW to 1.39×10^2 cfu/ml at PRoW compared to control of 1.43×10^2 cfu/ml during the dry season. Dry season values were higher than wet season levels particularly at the control. HUB/THB ratios were generally lower than 10% which is the limit signifying mineral oil pollution in environment (Atlas, 1985).

Total Heterotrophic Fungi(THF)

THF ranged from 0.37×10^3 cfu/ml at PRoW to 0.42×10^3 cfu/ml at PW compared to control of 0 cfu/ml during the wet season and from 0.49×10^3 cfu/ml at PRoW to 0.91×10^3 cfu/ml at EW compared to 0.54×10^3 cfu/ml at control during the dry season. Levels were higher during the dry season compared to wet season including the control but the control was not different from study location except during the wet season when THF was undetected at control.

Hydrocarbon Utilizing Fungi (HUF)

HUF ranged from 0.25×10^2 cfu/ml at EW to 0.54×10^2 cfu/ml at PW compared to control of 3.55×10^2 cfu/ml during the wet season and from 0.16×10^2 cfu/ml at EW to 0.18×10^2 cfu/ml at PW compared to control of 0 cfu/ml. Wet season was higher than dry season with the highest level at the control while during the dry season it was not detected at the control.

Coliform bacteria

Total coliform ranged from 4 MPN/100ml at EW to 4.75 MPN/100ml at PW compared to control of 0.8 MPN/100ml during the wet season and from 3 MPN/100 ml at EW to 11 MPN/100ml at PW compared to 4.5 MPN/100ml at the control during the dry season. Dry season levels were higher than those of the wet season including at the control. Levels at control were significantly lower than those of the study locations during the wet season. Most drinking water quality standards recommend that drinking water should be devoid of all Coliform bacteria. Although coliform bacteria are not harmful in most cases, their presence in water supply it is an indicator of

the potential occurrence of other harmful and disease causing bacteria and such waters are considered as being presenting a potential health hazard and classified as unsafe for human consumption.

Table 4.9c: Summary results of Microbiological measurements in boreholes around Enwhe Field during the wet season

Parameters	Unit	Wet Season				Dry Season			
		Proposed wells	Pipeline RoW	Existing wells	Control	Proposed wells	Pipeline RoW	Existing wells	Control
		Mean±Std	Mean±Std	BH6	Mean±Std	Mean±Std	Mean±Std	BH6	Mean±Std
Coliform Count	MPN/100ml	4.75±2.60	4±2.23	4	0.8±0.28	11±3.79	8.5±3.89	3	4.5±0.71
HUB	cfu/ml x 10 ²	1.41±0.6	1.37±0.49	1.2	0	1.35±0.51	1.39±0.55	1.18	1.43±0.6
HUF	cfu/ml x 10 ²	0.54±0.55	0.3±0.12	0.25	3.55±1.63	0.18±0.05	0.16±0.04	0.16	0
THB	cfu/ml x 10 ³	4.88±1.68	5.4±1.29	4.7	0	1.75±0.7	1.94±0.81	2.54	2.55±0.58
THF	cfu/ml x 10 ³	0.42±0.21	0.37±0.11	0		0.51±0.48	0.49±0.28	0.91	0.54±0.26

Source: Enwhe Field Development EIA Field Data September,2016 (Wet season) and November, 2016 (Dry Season)

4.7.9: Vegetation

Vegetation Cover structure

A total of 116 species belonging to 49 plant families were identified during the two season field study within the Enwhe field. The largest families by species representation are Poaceae >Euphorbiaceae >Mimosoideae>Papilionaceae>Moraceae>Palmae. The vegetation in Enwhe is divided into flood forest, low land forest, secondary, agricultural and homestead gardens. The vegetation comprised of trees (29.91%), herbaceous plants (14.53%), shrub (13.68%), climbers (8%) and grasses 4%. The vegetation was further classified using Raunkiaer's life form system for Phanerophytes (plants that project their stems into the air) with subgroupings of Nanophanerophytes (24.35%), Mesophanerophytes (20%), Microphanerophytes (17.39%), and Megaphanerophytes (15.65%). The dominance of the Trees and a remarkable proportion of the Megaphanerophytes, is consistent with both the flood forest and Lowland rain forest habitats. The prominence of the Nanophanerophytic life form, and species of the family Poaceae across the vegetation is indicative of degraded forest vegetation ecosystem as a result of agriculture, lumbering, and settlement encroachment.

Vegetation Structure and Species Composition

The vegetation in the study area is predominantly Flood plain vegetation with patches of Riparian swamp, and freshwater swamp habitat in non-tidal areas. Flood plain has been converted into Rubber plantations in some areas (VG 37, 22, 23), otherwise the habitat is mostly Nanophanerophytic (VG 21, 24) and dominated by water loving/tolerant herbaceous species. Among the recorded herbaceous species were: *Clappertonia ficifolia*, *Panicum subalbidum*, and *Alchornea laxiflora*. Some of the trees identified in the study area were: *Hevea brasiliensis* (Plate 4.2a) *Elaeis guineensis*, *Pentades matyracea*, *Anthocleista nobilis*, *Anthocleista djalonsensis*, *Cleistopholis patens*, (VG18,24,27), *Laccosperma secundiflorum* and *Psidium guajava*. Vegetation reaches 6 meters in the homogeneous communities with a ground cover of over 60% provided by *Pterocarpus* sp.; while the ground cover was less in heterogeneous communities and flood plains.

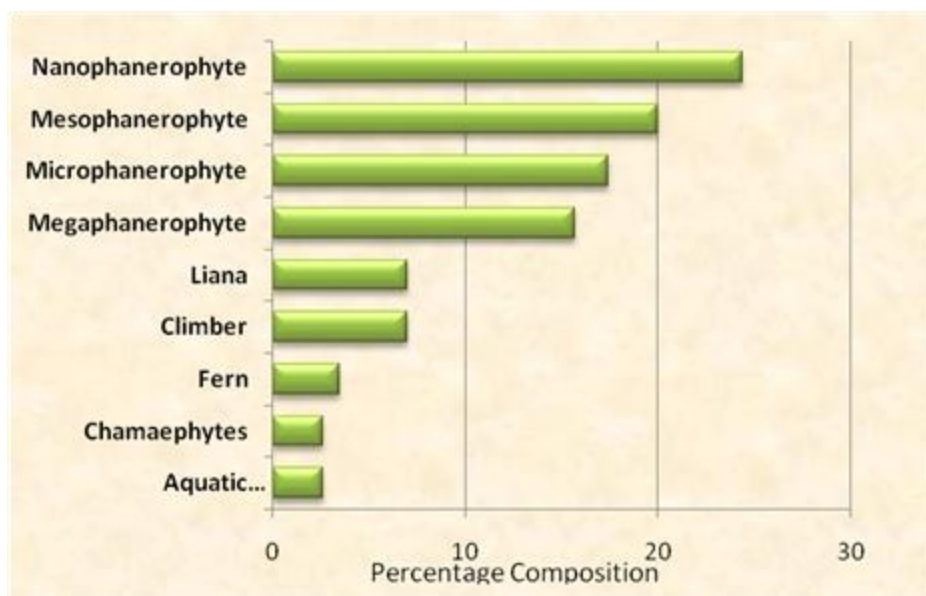


Fig. 4.5: Classification of the plants in Enwhe field

The vegetation in the area was classified into four categories:

1. Niger Delta Flood Forest
2. Lowland Tropical Rainforest.
3. Secondary Vegetation
4. Agricultural Farmlands and Home Gardens

The vegetation in the region is circumscribed on the annual Niger River flooding of the area; through both the Orashi River with its distributaries, and the Nun River near Gbaran, which itself is a distributary of the Niger. The Field study revealed that the flood season lasted 5 weeks, beginning in late September, and reached its peak in the month of October subsiding in early November.

The seasonal flood prone areas occur along most of the water courses in the area and the covered a distance of kilometre along the Orashi basin. In most cases, water volume rises above the 3 – 7 feet steep banks of the Orashi; while the tributaries, flood the area to 4-5.5 feet depth, above ordinarily dry grounds for over a month. The drying up, and receding of the floods leaves behind a high water mark on vegetation. The vegetation especially the grasses die during the period of flooding and decompose enriching the soil in the area as shown in Plate 4.2a.

The plants found in the lowland tropical forest are shown in Plate 4.2b it is composed of grasses, interspersed with *Elaeis guinensis*. There were rich biodiversity in Enwhe as was indicated by the number of plants and their ethanobotanical uses (Table 4.10a). *Cola nitida* (Kola nut) is used in traditional ceremonies while *Mangifera indica* (Mango) bark, *Garcinia kola* (bitter kola) and *Alchornea spp* (Christmas bush) were used as medicinal plant. *Pycnanthus angolensis*,

Chrysophyllum giganteum, *Lovoa trichiliodes* and *Zanthoxylum lemairei* are sources of timber used in construction and furniture making.

The agricultural farmland and home gardens (Plate 4.2c) comprised of plants belonging to the following Families namely: Moraceae, Caricaceae, Solaneaceae, Musaceae, Rutaceae, Poaceae, Bromeliaceae and Myrtaceae which were, represented by *Artocarpus communis* (Breadfruit) *Carica papaya* (Paw- paw), *Solanum melongena* (Garden egg,), *Musa paradisiacal* (Plantain), Citrus, Pineapple, and *Psidium guajava* (Table 4.10b.) Some of the edible green leafy vegetables in Enwhe belong to Family Asteraceae, Cucurbitaceae and Amaranthaceae and examples include *Veronia armygalatina*, (Bitterleaf), *Telfera occidentalis* (Fluted pumkin) and green vegetable

Pathological investigations revealed that in cassava plants, a virus called the African Cassava Mosaic Virus of the genus *Begomo virus* were responsible for the discoloration observed. Minor incidences of the fungal brown leaf spot disease (caused by *Cercosporidium* sp) was observed on other cassava farms (Plate 4.2d) and on *Alchornea Spp*.

Farmland crops include cassava, maize, yam serve as food source in the study area. The Enwhe forest has Timber forest resources. Twenty-three (23) Timber species were identified from the study area out of which only five (5) were not of commercial value. Thirteen (13) timber species were hard wood species which indicated that lumbering has been very severe and is ongoing (Plate 4.2e) Igben and Ohiembor(2015) inferred that lumbering is a factor causing deforestation in the freshwater swamp forest in Delta State, Nigeria. They further observed that trees that are felled for timber constitute the natural biodiversity of the area and were therefore critical in the ecological balance of the freshwater swamp forest zone. Batool and Hussain (2016) concluded that deforestation resulted in habitat loss. Amaku *et al.*(2016) demonstrated that deforestation resulted in loss of valuable plant species, extinction of species and reduced species richness and evenness.

Table 4.10a: Ethnobotanical uses of Plants

SPECIES NAME	LOCAL / COMMON NAME	ETHNOBOTANICAL USES
<i>Albizia spp</i>	Albizia	Timber / domestic fuel wood
<i>Alchornea spp</i>	Christmas Bush	Medicinal
<i>Alstonia boonei</i>	Stool wood/Alstonia	Timber: Soft wood:
<i>Anthocleista spp</i>		Roots Medicinal: Antihypertensive, Cure erectile dysfunction, Antidiabetic
<i>Bambusa vulgaris</i>	Bamboo	Construction
<i>Calamus deeratus</i>	Water Cane; Rattan	Cane furniture, and domestic handicraft
<i>Ceiba pentandra</i>	Silk Cotton	Timber: Soft wood: Carvings, light construction, ply wood, veneer, particle boards, hand dug canoe

SPECIES NAME	LOCAL / COMMON NAME	ETHNOBOTANICAL USES
<i>Chromolaena odorata</i>	Awolowo, Shell company	Wound healing, Antimalarial
<i>Chrysophyllum giganteum</i>	Ochi = Ekpeye	Timber: Hand dug canoe, Paddle, Construction of Oil Milling canoe
<i>Cleistopholis patens</i>		Timber: Light wood
<i>Cnestis ferruginea</i>		Medicinal
<i>Cola gigantean</i>	Monkey kola	Edible fruit
<i>Cola nitida</i>	Kola nut	Stimulant, traditional/cultural/religious ceremonies
<i>Costus afer</i>	Monkey Sugar Cane	Antidehydrant, forest snack.
<i>Cylicodiscus gabunensis</i>		Timber: Hard wood; twigs for Fuel wood
<i>Elaeis guineensis</i>	Oil Palm	Fruit: Palm Oil; leaf for thatch/ broom making; sap wine, brew local gin
<i>Zanthoxylum lemairei</i>		Timber: Furniture
<i>Ficus exasperata</i>	Sand paper tree	Leaf: Medicinal, Abrasive
<i>Fleroya ledermannii</i>	Abura	Timber Commercial: Soft wood, light furniture
<i>Garcinia kola</i>	Bitter cola	Medicinal nuts, stimulant
<i>Hevea brasiliensis</i>	Rubber	Latex sap; Timber; Construction reinforcement
<i>Irvingia gabonensis</i> var. <i>Excelsa</i>	Ogbono	Seeds used for staple soup base
<i>Irvingia gabonensis</i> var. <i>Gabonensis</i>	Bush Mango; Ogbono	Edible fruit
<i>Klainedoxa gabonensis</i> var. <i>Oblongifolia</i>		Timber: Heavy Hard Wood
<i>Laccosperma secundiflorum</i>	Water Cane; Rattan	Domestic handicraft: Cane Chair, baskets, etc
<i>Leucaena leucocephala</i>	Owolowa= Ekpeye	Yam stake
<i>Lonchocarpus sericeus</i>		Timber: Hard wood; durable under water
<i>Lophira alata</i>	Adikolo = Ekpeye; Iron wood; Ekki	Hard Heavy wood: Hand dug Canoe, and paddle; Favourite for hand dug Oil milling Canoe; durable under water
<i>Lovoa trichilioides</i>	African walnut	Timber: Commercial
<i>Mangifera indica</i>	Mango	Bark Medicinal; Fruit Edible
<i>Milicia excels</i>	Diork = Ekpeye; Iroko;	Boundary Marker; Timber Commercial Hard wood

SPECIES NAME	LOCAL / COMMON NAME	ETHNOBOTANICAL USES
<i>Nauclea diderrichii</i>		Commercial Timber; Durable hard wood
<i>Newbouldia laevis</i>		Medicinal
<i>Oldfieldia africana</i>	African Oak	Timber: Commercial hard wood
<i>Pentaclethra macrophylla</i>	<i>Ugba</i>	Soup Condiment
<i>Pentadesma butyracea</i>		Timber: Hard wood, Rough construction
<i>Piptadeniastrum africanum</i>		Timber: Heavy Hard Wood
<i>Psydrax subcordatum</i>		Paddle construction, Poles; Fuel wood
<i>Pterocarpus santalinoides</i>		Roasted seeds edible; young leaves vegetable
<i>Pycnanthus angolensis</i>		Timber: Light wood, Ply board , Cabinet work
<i>Rauvolfia vomitoria</i>		Medicinal
<i>Spondianthus preussii</i>		Timber: Commercial Hard Heavy wood
<i>Spondias mombin</i>		Edible fruits
<i>Symphonia globulifera</i>		Timber: Construction
<i>Trichoscypha arborea</i>		Fuel wood, and poles
<i>Uapaca guineensis</i>		Timber: Commercial Hard Wood durable
<i>Vitex grandifolia</i>		Timber: Light Construction, Veneer



Plate 4.2a: A view of the structure of the flood plain vegetation systems in the study area



Plate 4.2b: Typical Low land forest vegetation in Enwhe



Plate 4.2d: Cassava pulp (*Akpu*) processing hub and market at Akiogbologbo (SWSD 7) from where *Akpu* is exported to Mbiama Market; Inset: Finished product.

Table 4.10b: Agricultural Farmlands and Home Gardens

Species Name	Family	Common Name	Major Class of Use
<i>Cocos nucifera</i>	Palmae	Coconut	Edible Fruit
<i>Artocarpus communis</i>	Moraceae	Bread Fruit	Edible Fruit
<i>Carica papaya</i>	Caricaceae	Pawpaw	Edible fruit
<i>Ananas comosus</i>	Bromeliaceae	Pineapple	Edible Fruit
<i>Annona muricata</i>	Annonaceae	Sour-sop	Edible Fruit
<i>Theobroma cacao</i>	Sterculioideae	Cocoa	Edible fruit
<i>Psidium guajava</i>	Myrtaceae	Guava	Edible Fruit
<i>Dacryodes edulis</i>	Burseraceae	Native/African pear	Edible Fruit
<i>Saccharum officinarum</i>	Poaceae	Sugar cane	Edible fruit

Species Name	Family	Common Name	Major Class of Use
<i>Solanum melongena</i>	Solanaceae	Garden egg	Edible fruit
<i>Musa paradisiaca</i>	Musaceae	Plantain	Edible fruit
<i>Citrus sinensis</i>	Rutaceae	Sweet Orange	Edible fruit
<i>Citrus limon</i>	Rutaceae	Lime	Edible fruit
<i>Citrus auriculata</i>	Rutaceae	Tangerine	Edible fruit
<i>Musa acuminata</i>	Musaceae	Banana	Edible fruit
<i>Dioscorea alata</i>	Dioscoreaceae	Water Yam	Edible tuber
<i>Dioscorea rotundata</i>	Dioscoreaceae	White Yam	Edible tuber
<i>Manihot esculenta</i>	Euphorbiaceae	Cassava	Edible roots
<i>Colocasia esculenta</i>	Araceae	Cocoyam	Edible tuber
<i>Vernonia amygdalina</i>	Asteraceae	Bitter leaf	Green leafy vegetable
<i>Telfaria occidentale</i>	Cucurbitaceae	<i>Ugwu</i> or <i>Ugu</i> leaf	Green leafy vegetable
<i>Celosia sp</i>	Amaranthaceae	Green vegetable	Green leafy vegetable
<i>Amaranthus sp</i>	Amaranthaceae	Green vegetable	Green leafy vegetable
<i>Abelmoschus esculenta</i>	Malvoideae	Okra	Vegetable
<i>Lycopersicon esculentum</i>	Solanaceae	Tomato	Vegetable
<i>Capsicum spp</i>	Solanaceae	Pepper	Vegetable
<i>Ocimum gratissimum</i>	Labiatae	Scent/Sweet basil leaves	Condiment/Medicinal herb
<i>Cassia alata</i>	Caesalpinioideae		Medicinal herb
<i>Cymbopogon citratus</i>	Poaceae	Lemon grass	Medicinal herbs



Plate 4.2e: *Begomo* virus Discolouration of Cassava

The ecosystem services provided by the plants in this environment include food such as yam, Cassava, vegetables and fruits. Regulatory and supporting services provided by the plants in the study area were nutrient recycling, shielding of soil from erosion, siltation control and evapotranspiration. The flooding that occurred in the area for 5 weeks slowed down flow of water through natural retention and allowed sediments deposit keeping it out of the water body. The trees and shrubs and grasses in this area provided shelter for the variety of birds and arthropods found in Enwhe field.

4.7.10 Wildlife

Invertebrates

The terrestrial wildlife of the study area revealed that there were abundance of invertebrates including Arthropods and Molluscs because of forest and lowland vegetation. The Arthropods were mainly beetles (Coleoptera), butterflies (Lepidoptera), flies (Diptera), grasshoppers (Orthoptera), and dragon flies (Odonata). Over 10 families of beetles and butterflies were observed as shown in Table 4.11a. The Lepidopterans were represented by Families such as Papilionidae, Pieridae, Nymphalidae and Acraeidae. The terrestrial mollusc consists of 21 species belonging to six families– Achatinidae, Subulinidae, Succineidae, Streptaxidae, Urocyclidae, and Veronicellidae. The carnivorous snails of the family Streptaxidae were the most dominant with the highest number of species. The giant African land snail, *Archachatina marginata*, was the most conspicuous and most commercially exploited molluscan resource in the region. Molluscs are important in nutrient recycling and soil mineralization. Table 4.11b provides a checklist of the land molluscan species recorded from the area.

Table 4.11a: Arthropods composition in Enwhe field

Beetles	Family	Common names	
	Scarabaeidae	Scarab beetles	<i>as Scarabaeus sacer</i>
	Carabidae	Carabid beetles	<i>Carabidae spp</i>
	Curculionidae	Weevils	<i>Curculionidae spp</i>
	Cicindelidae	Tiger beetles	<i>Cicindelidae latreille</i>
	Lampyridae	Fire flies	<i>Lampyridae spp</i>
	Chrysomelidae	Leaf beetles	<i>Chrysomelidae spp</i>
	Coccinellidae	Lady beetles	<i>Coccinellidae spp</i>
	Cerambycidae	Long-horned beetles	<i>Cerambycidae spp</i>
	Phalacridae	Fungus beetles	<i>Phalacridae spp</i>
	Meloidae	Blister beetles	

Lepidoptera	Papilionidae	Moths/butterfly	<i>Papilio</i> spp.
	Pieridae	Moths/butterfly	<i>Appias sylvia</i>
	Danaidae	Moths/butterfly	<i>Danaus</i> spp.
	Satyridae	Moths/butterfly	<i>Elymnias</i> sp.
	Nymphalidae	Moths/butterfly	<i>Charaxes</i> spp.
	Acraeidae	Moths/butterfly	<i>Acraea</i> sp.
	Zygaenidae	Moths/butterfly	<i>Charidea</i> sp.
	Arctiidae	Moths/butterfly	<i>Aganais speciosa</i>
	Lymantriidae	Moths/butterfly	<i>Stracena promelena</i>

Table 4.11b: Mollusc composition in Enwhe field

Family	Species
Achatinidae	<i>Archachatina marginata</i> <i>Archachatina papyracea</i> <i>Limicolaria flammea</i> <i>Lignus</i> sp.
Streptaxidae	<i>Gonaxis camerunensis</i> <i>Gulella germaini</i> <i>Gulella io</i> <i>Gulella monodon</i> <i>Gulella opoboensis</i> <i>Gulella pupa</i> <i>Ptychotrema aequatoriale</i> <i>Ptychotrema shagamuense</i>
Subulinidae	<i>Curvella feai</i> <i>Kempiochoncha</i> sp. <i>Pseudopeas</i> sp. <i>Subulina striatella</i> <i>Subulina</i> sp. <i>Subulona patalus</i> <i>Subulona</i> sp.
Succineidae	<i>Quickia</i> sp.
Urocyclidae	<i>Trochozonites talcosus</i> <i>Trochozonites</i> sp
Veronicellidae	<i>Pseudveronicella liberiana</i>

Amphibians and Reptiles

Bufo regularis were abundant in the area however, tree frogs *Afrixalus dorsalis* and *Hyperriolus quttulus* were rare. The reptiles (Table 4.11c) were represented by Chelonia, Crocodilias and Squamata at least 14 species of chameleons, geckos, lizards, snakes, skinks, and tortoises. *Osteolaemus tetraspis* (Dwarf Crocodile) and *Crocodylus niloticus* (Nile Crocodiles) were rare because they were hunted for food while the Wall gecko, stinks and Agama lizards were common. The lizards were many because they were not used as food. *Python regius* (Royal Pythons) were rare while cobra, snake and viper were common in the study area. The forest turtle, *Pelusios niger* and the serrate hinge –back tortoise *Kinixys erosa* were rare in Enwhe.

Table 4.11c: Amphidians and Reptiles composition in Enwhe field

Class	Order	Family	Common name	Scientific name	Status	
Reptilia	Chelonia	Pelomedusidae	West African Black Forest Turtle	<i>Pelusios niger</i>	Rare	
		Testudinidae	Serrate Hinge-back tortoise	<i>Kinixys erosa</i>	Rare	
	Crocodylia	Crocodylidae	Dwarf Crocodile	<i>Osteolaemus tetraspis</i>	rare/extinct	
			Nile Crocodile	<i>Crocodylus niloticus</i>	Extinct	
	Squamata	Agamidae	Agama lizard	<i>Agama agama</i>	Abundant	
			Gekkonidae	Wall Gecko	<i>Hemidactylus brooki</i>	Common
		Scincidae		Skinks	<i>Mabuya sp</i>	Common
						<i>Lygosoma sp</i>
					<i>Melanoceps sp.</i>	Common
		Varanidae	Nile Monitor	<i>Varanus niloticus</i>	Rare	
		Boidae	Royal Python	<i>Python regius</i>	Rare	
		Colubridae	Common File Snake	<i>Mehelya crossi</i>	Common	
			Lined House Snake	<i>Boaedon lineatus</i>	Common	
			Common Hedge Snake	<i>Philothamnus irregularis</i>	Rare	
	Elapidae	Black Cobra	<i>Naja melanoleuca</i>	Abundant		
Viperidae	common vipers	<i>Vipera sp.</i>	Abundant			
Amphibia		Pipidae	Tongueless frog	<i>Hymenochirus boettgeri</i>	Rare	
		Bufonidae	Toads	<i>Bufo regularis</i>	Abundant	
		Ranidae	True frogs		<i>Hylarana albolabris</i>	Rare
					<i>Dicroglossus occipitalis</i>	Abundant
		Rhychophoridae	Treefrogs	<i>Afrixalus dorsalis</i>	Rare	
		<i>Hyperoliolius guttulatus</i>	Rare			

Avifauna

The avian population in the Enwhe community was as assemblage of birds from diverse habitat, since birds prefer habitats with suitable vegetation for nest building and feeding (Table 4.11d). Some of the birds are shown in Plate 4.3a. Cattle egret *Ardeola ibis*, Alcedo *cristata*. (King fisher bird), *Tockus fasciatus* (Black and White Hornbill), *Melaenormis edoliodes* (Black flycatcher), *Milvus migrans* (Black kite), *Actitis hypoleucos* (common piper) and *Nectarinia cuprea* (common sunbird). The different types of birds settled in the area of the forest where their food is readily available. Insectivorous birds dominated the farmland area of the forest such as forest robin, waxbills and grey headed sparrow while the cattle egret, pied crow and hornbill and black flycatcher were found in forest and lowland forest. Birds play major role in seed dispersal in the forest.

Mammals

The mammalian fauna recorded within the study area were 24 species of mammals (Table 4.11e). These species belong to 6 mammalian Orders, 16 Families, and 23 Genera. They include the rodents (Rodentia), primates (Primates), pangolins (Pholidota), carnivores (Carnivora), insectivores (Insectivora), and ungulates (Artiodactyla). The Rodentia includes *Anomalurus beecrofti*, *Atherurus africanus* and *Cricetomys emini* which were classified as endangered species while *Rattus rattus* and *Mastomys natalensis* were common in the area. The primates represented by *Perodicticus potto*, *Galagoides demidovii*, *Cercopithecus mona* *Cercopithecus sclateri* were also endangered species while *Arctocebus calabarensis* were common in the community. Some of the carnivore found in the study area were *Viverra civetta*, *Nandinia binotata*, *Genetta poensis*, *Atilax palidinosus*, *Herpsetes ichéumou* and *Potamochoerus porcus* were facing endangerment.

The Artiodactyla identified in the study area include *Potamochoerus porcus*, *Tragelaphus scriptus*, *T. speki* and *Cephalophus maxwell*(Duiker) and the conservation status indicated that they were listed as threatened animals. These mammals were reported to be present either within or in the surrounding riparian forest. While Table 4.11e. shows the list of the mammals in the community indicating common, vulnerable and mammals facing endangerment in the community due to hunting of the animals for food. Some of these animals serve as totem. Batool and Hussain (2016) opined that animals interact with their environment for energy gain and protection but lumbering has contributed to destruction of the environment. Other factors that affect wildlife include habitat fragmentation which affects breeding of animals and their foraging. These factors contribute to loss of biodiversity.

Table 4.11d: Avian fauna composition in the Enwhe field

Common Names	Scientific Names
Lily trotter	<i>Actophilornis Africana</i>
Malachite kingfisher	<i>Alcedo cristata</i>
Little Greenbul	<i>Andropadus virens</i>
Collard Sunbird	<i>Anthreptes collaris</i>
Plain-backed Pipit	<i>Anthus leucophrys</i>
Little African Swift	<i>Apus affinis</i>
European swift	<i>Apus apus</i>
Cattle egret	<i>Ardeola ibis</i>
African Green Pigeon	<i>Treron calva</i>
African Harrier Hawk	<i>Polyboroides typus</i>
Barn Swallow	<i>Hirundo rustica</i>
Black & white Hornbill	<i>Tockus fasciatus</i>
Black & white Mannikin	<i>Lonchura poensis</i>
Black Flycatcher	<i>Melaenormis edoliodes</i>
Black Kite	<i>Milvus migrans</i>
Bronze Mannikin	<i>Lonchura cucullatus</i>
Bush Shrike	<i>Melaconotus cruentus</i>
Bush Sparrow	<i>Petronia dentate</i>
Cassin's Grey Flycatcher	<i>Muscicapa casini</i>
Chattering Cisticola	<i>Cisticola erythrops</i>
Common Bulbul	<i>Pycnonotus barbatus</i>
Common Sandpiper	<i>Actitis hypoleucos</i>
Copper Sunbird	<i>Nectarinia cuprea</i>
Fire-spotted Woodpecker	<i>Aropetheria punctuligera</i>
Forest Robbin	<i>Stiphornis erythrothorax</i>
Forest Scrub-robbin	<i>Cercotrichas leucosticta</i>
Great Blue Turaco	<i>Corythaeola cristata</i>

Common Names	Scientific Names
Green-crested Turaco	<i>Taurao persa</i>
Grey-headed Sparrow	<i>Passer griseus</i>
Little Bee-eater	<i>Merops pusillus</i>
Lizard buzzard	<i>Kaupifalco monogrammicus</i>
Painted Snipe	<i>Rostratula benghalensis</i>
Pied Crow	<i>Corvus albus</i>
Pigmy Woodpecker	<i>Verreauxia africana</i>
Pin-tailed Whydah	<i>Vidua macroura</i>
Palmnut Vulture	<i>Gypoierax angolensis</i>
Red-billed Dove	<i>Tutur afer</i>
Red-eyed Dove	<i>Streptopelia vinacea</i>
Senegal Coucal	<i>Centropus senegalensis</i>
Senegal Fire-finch	<i>Lagonosticta senegala</i>
Senegal kingfisher	<i>Halcyon senegalensis</i>
Superb Sunbird	<i>Nectarinia superba</i>
Swamp Palm Bulbul	<i>Thescelocichla leucopleurus</i>
Tambourine Dove	<i>Tutur tympanistra</i>
Ussher's Flycatcher	<i>Artomyias ussheri</i>
Village Weaver	<i>Ploceus cucullatus</i>
West African Thrush	<i>Turdus pelios</i>
White-throated Blue Swallow	<i>Hirundo nigrata</i>
Yellow-mantled Whydah	<i>Euplectes macrourus</i>
Yellow Wagtail	<i>Motacilla flava</i>
Yellow-throated Long-claw	<i>Macronyx croceus</i>



Plate 4.13: Common Avian fauna in Enwhe field (Cattle egret)

Table 4.11e: Mammalian fauna composition in the Enwhe field

Class	Order	Family	Common names	Scientific names	Abundance status	Conservation status
Mammalia	Primates	Lorisidae (potto)	Potto	<i>Perodicticus potto</i>	Rare	Endangered
			Angwantibo	<i>Arctocebus calabarensis</i>	Common	Least Concern
		Galagidae (bushbabies)	Dwarf Galago	<i>Galagoides demidovii</i>	Rare	Endangered
		Cercopithecidae (monkeys)	Mona monkey	<i>Cercopithecus mona</i>	Rare	Threatened
			Sclater's Monkey	<i>Cercopithecus sclateri</i>	Rare	Vulnerable
			Olive Colobus	<i>Procolobus verus</i>	Common within its range	Near Threatened
	Pholidota (Pangolins)	Manidae	Tree Pangolin	<i>Manis tricuspis</i>	Rare	Endangered
	Insectivora	Erinaceidae	Hedgehog	<i>Erinaceus albiventris</i>	Common	Vulnerable
		Soricidae (Shrews)	Forest Shrew	<i>Crocidura odorata</i>	Common	Not Threatened
	Rodentia (rodents)	Anomaluridae	Beecroft's Flying-squirrel	<i>Anomalurus beecrofti</i>	Rare	Endangered
		Hystricidae	Brushtailed Porcupine	<i>Atherurus africanus</i>	Abundant	Endangered
		Cricetidae	Emin's Giant-rat	<i>Cricetomys emini</i>	Abundant	Vulnerable
			Gambian Giant Rat	<i>Cricetomys gambianus</i>	Abundant	Vulnerable
		Thryonomidae	Greater Cane Rat	<i>Thryonomys swinderianus</i>	Abundant	Vulnerable
		Sciuridae	Giant Forest Tree-squirrel	<i>Protexerus stranger</i>	Rare	Threatened

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Class	Order	Family	Common names	Scientific names	Abundance status	Conservation status
			Red-legged Sun-squirrel	<i>Heliosciurus rufobrachium</i>	Rare	Threatened
		Muridae	Black Rat	<i>Rattus rattus</i>	Abundant	Not Threatened
			Multimammate Mouse	<i>Mastomys natalensis</i>	Common	Not Threatened
			Pygmy Mouse	<i>Mus minutoides</i>	Common	Not Threatened
			Three-striped Mouse	<i>Hbyomys trivirgatus</i>	Common	Not Threatened
	Carnivora (Carnivores)	Viverridae (civet, genets & mongoose)	African Civet	<i>Viverra civetta</i>	Rare	Threatened
		Nandiniidae	Two-spot Palm Civet	<i>Nandinia binotata</i>	Common	Endangered
			Forest Genet	<i>Genetta poensis</i>	Rare	Threatened
		Herpestidae	Marsh Mongoose	<i>Atilax palidinosus</i>	Rare	Threatened
			Egyptian Mongoose	<i>Herpestes ichneumon</i>	Rare	Threatened
	Artiodactyla	Suidae (pigs)	Red River-hog	<i>Potamochoerus porcus</i>	Rare	Threatened
		Bovidae (Antelopes)	Bushbuck	<i>Tragelaphus scirptus</i>	Common	Threatened
			Sitatunga	<i>Tragelaphus spekii</i>	Rare	Threatened
			Maxwell's Duiker	<i>Cephalophus maxwelli</i>	common	Threatened
	Cetartiodactyla	Suidae	Bushpig	<i>Potamochoerus larvatus</i>	Rare	Threatened
	Sirenia	Trichechidae	African Manatee	<i>Trichechus senegalensis</i>	Uncertain	Vulnerable

4.7.11 Aquatic Ecology

4.7.11.1: Phytoplankton studies

The summary of results of phytoplankton studies in the study area and controls are presented in Tables 4.12a to 4.12c for the wet and dry seasons respectively. Detailed results are presented in Appendix 4.6.11a & b. All results are presented in relation to sampling strategy to cover the Proposed Wells (PW), Pipeline Right of Way (PRoW), Existing Wells (PW) and Pipeline River Crossing (Upstream, Midstream and Downstream) locations compared to control.

Phytoplankton Composition

The phytoplankton was composed of Bacillariophyceae, Chlorophyceae, Cyanophyceae, Dinophyceae and Euglenophyceae with no changes in composition between the wet and dry seasons. The checklist of Phytoplankton species identified in the study area and controls is presented in Table 4.12a. The percentage abundance of the phytoplankton is shown in Fig. 4.6a. The phytoplankton distribution followed the order: Bacillariophyceae > Chlorophyceae > Cyanophyceae > Dynophyceae > Euglenophyceae while the species distribution followed the order: Bacillariophyceae >Chlorophyceae >Cyanophyceae >Euglenophyceae =Dynophyceae during the wet season. During the dry season, the abundance followed the order: Bacillariophyceae >Chlorophyceae >Cyanophyceae > Euglenophyceae > Dynophyceae while the species distribution followed the order: Bacillariophyceae >Chlorophyceae >Cyanophyceae >Euglenophyceae =Dynophyceae. Bacillariophyceae was the most abundant and dominant species during the both seasons while Dinophyceae was the least abundant and dominant. The dominance of Bacillariophyceae (diatoms) in the phytoplankton of Nigerian waters is widely reported and is also common in most tropical systems (RPI/NNPC, 1985, Akpan, 2006)

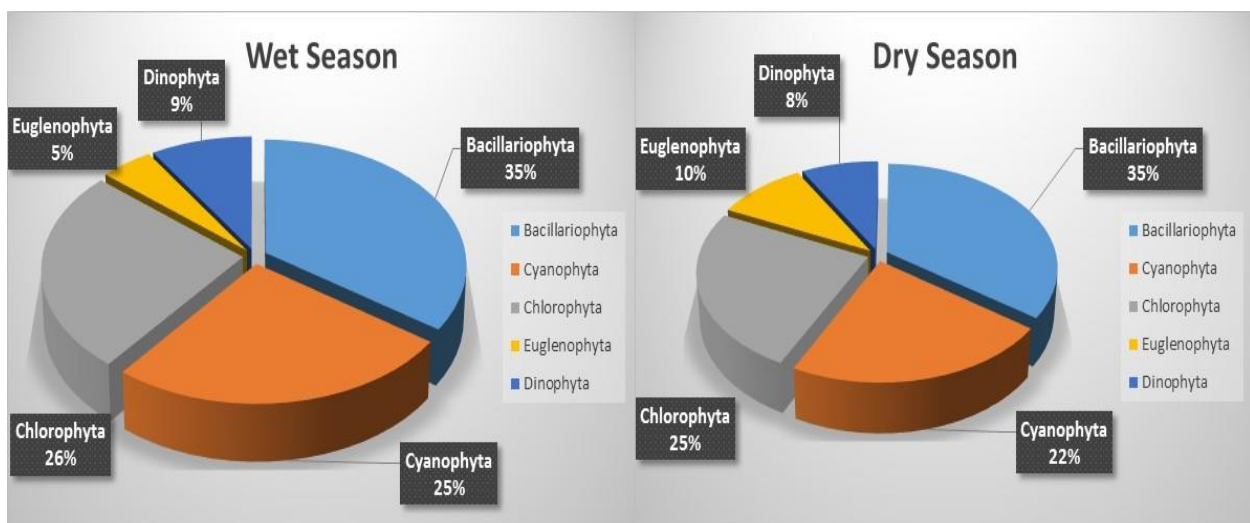


Fig. 4.6a: Relative abundance of Phytoplankton in the Study area

The spatio-seasonal distribution of the phytoplankton in the study area is shown in Fig. 4.6b. Phytoplankton abundance was significantly higher during the wet than dry season for all species except Euglenophyceae. Most studies report the opposite trend where dry season shows higher levels of phytoplankton abundance and species diversity than the wet season (Akpan, 2006). The trend observed in this study may be attributed to the seasonal distribution of phytoplankton nutrients where the nutrients (nitrate, phosphate and silicate) were significantly higher during the wet than the dry season. Phytoplankton growth is directly dependent on availability of nutrients. It is also possible that some species were washed into the river from the catchment during rains leading to higher abundance in the wet season

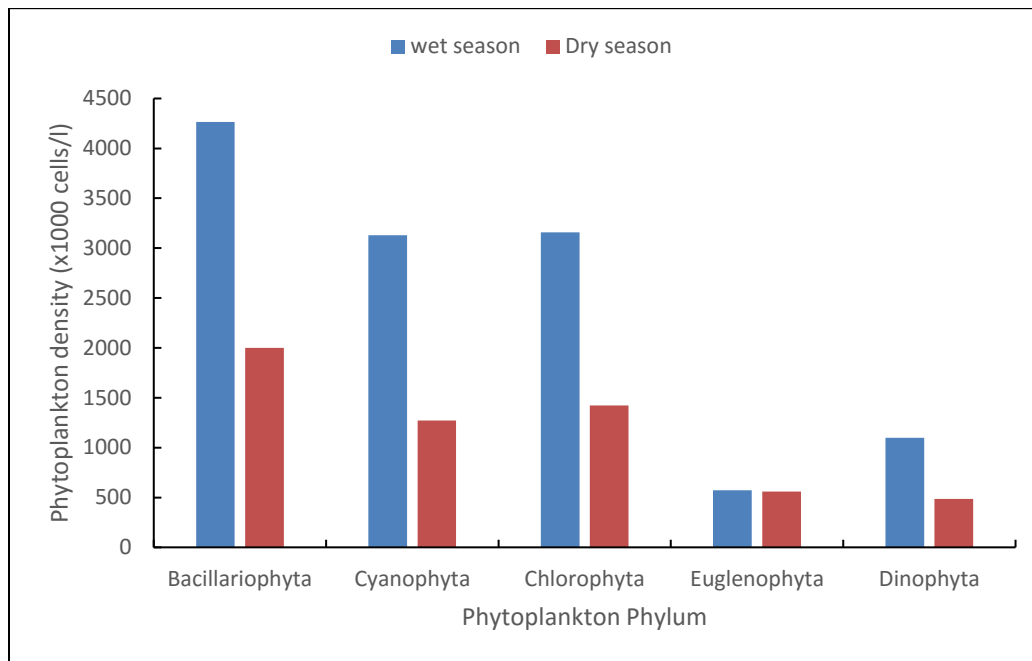


Fig. 4.6b: Spatial and Seasonal variation in Phytoplankton abundance at the study location

Phytoplankton Diversity

The spatial and seasonal variations in diversity indices of phytoplankton in the study area is presented in Tables 4.6.11.2a & b for the wet and dry seasons respectively. Diversity measures have important applications in aquatic ecosystems studies. In environmental monitoring, the adverse effects of pollution are known to result in the reduction of diversity or changes in the composition of species abundance. According to Rosenberg (1976) and Patrick (1973) polluted ecosystems display a reduction in diversity. Stoermer (1984) have discussed the role of phytoplankton species and assemblage as bio-indicators.

Table 4.12a: Checklist of Phytoplankton in aquatic systems around Enwhe Field

S/N	Wet Season					Dry Season				
	Bacillariophyta	Cyanophyta	Chlorophyta	Euglenophyta	Dinophyta	Bacillariophyta	Cyanophyta	Chlorophyta	Euglenophyta	Dinophyta
1	<i>Amphora ovails</i>	<i>Anabaena circinalis</i>	<i>Atlisdesmusfalcatus</i>	<i>Euglena acus</i>	<i>Ceratium birundinella</i>	<i>Amphora ovails</i>	<i>Anabaena circinalis</i>	<i>Atlisdesmusfalcatus</i>	<i>Euglena acus</i>	<i>Ceratium birundinella</i>
3	<i>Astenonella foremosc</i>	<i>Anabaena flos-aque</i>	<i>Chlorella vulgaris</i>	<i>Euglena gracilis</i>	<i>Chorococcus</i>	<i>Astenonella foremosc</i>	<i>Anabaena flos-aque</i>	<i>Chlorella vulgaris</i>	<i>Euglena gracilis</i>	<i>Chorococcus</i>
4	<i>Coscinodiscus radiata</i>	<i>Anacystiscyance</i>	<i>Closterium moniferum</i>	<i>Euglena viridis</i>	<i>Peridinium</i>	<i>Coscinodiscus radiata</i>	<i>Anacystiscyance</i>	<i>Closterium moniferum</i>	<i>Euglena viridis</i>	<i>Peridinium</i>
5	<i>Cyclotella bodanica</i>	<i>Coelophaerium sp.</i>	<i>Clostrerium aculare</i>			<i>Cyclotella bodanica</i>	<i>Coelophaerium sp.</i>	<i>Clostrerium aculare</i>		
6	<i>Cymbella ventricosa</i>	<i>Cxoiphasphaerialacustris</i>	<i>Pediastrum boryanum</i>			<i>Cymbella ventricosa</i>	<i>Cxoiphasphaerialacustris</i>	<i>Pediastrum boryanum</i>		
7	<i>Diatom cvulgare</i>	<i>Merispomediaelegans</i>	<i>Pediastrum simplex</i>			<i>Diatom cvulgare</i>	<i>Merispomediaelegans</i>	<i>Pediastrum simplex</i>		
8	<i>Gamphonema germinatum</i>	<i>Microcystis aeruginosa</i>	<i>Protococcus sp.</i>			<i>Gamphonema germinatum</i>	<i>Microcystis aeruginosa</i>	<i>Protococcus sp.</i>		
9	<i>Gyrosigma sp.</i>	<i>Nostoc</i>	<i>Scenedesmus</i>			<i>Gyrosigma sp.</i>	<i>Nostoc</i>	<i>Scenedesmus</i>		
10	<i>Melosira granulate</i>	<i>Oscillaturial acustris</i>	<i>Spirogyra communis</i>			<i>Melosira granulate</i>	<i>Oscillaturial acustris</i>	<i>Spirogyra communis</i>		
11	<i>Navicula radiosa</i>	<i>Phoridiumsp</i>	<i>Staurastrum angulum</i>			<i>Navicula radiosa</i>	<i>Phoridiumsp</i>	<i>Staurastrum angulum</i>		
12	<i>Nitschia palae</i>	<i>Spirulinamasartii</i>	<i>Staurastrum paradaxum</i>			<i>Nitschia palae</i>	<i>Spirulinamasartii</i>	<i>Staurastrum paradaxum</i>		
13	<i>Suriella capronii</i>		<i>Volvox</i>			<i>Suriella capronii</i>		<i>Volvox</i>		
14	<i>Synedra ulna</i>		<i>Zygnema sterile</i>			<i>Synedra ulna</i>		<i>Zygnema sterile</i>		
15	<i>Tabellaria</i>					<i>Tabellaria</i>				

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S/N	Wet Season					Dry Season				
1	Bacillariophyta	Cyanophyta	Chlorophyta	Euglenophyta	Dinophyta	Bacillariophyta	Cyanophyta	Chlorophyta	Euglenophyta	Dinophyta
Density (x1000/l)	4265	3128	3157	571	1099	1999	1270	1423	559	484
% Abundance	34.90	25.60	25.83	4.67	8.99	27.94	19.98	22.39	8.80	7.62
Abundance order	Bacillariophyceae>Chlorophyceae>Cyanophyceae>Dynophyceae>Euglenophyceae					Bacillariophyceae>Chlorophyceae>Cyanophyceae>Euglenophyceae > Dynophyceae				
Species order	Bacillariophyceae>Chlorophyceae>Cyanophyceae>Euglenophyceae>Dynophyceae					Bacillariophyceae>Chlorophyceae>Cyanophyceae>Euglenophyceae>Dynophyceae				
<i>Source: Enwhe Field Development EIA Field Data September,2016 (Wet season)</i>										

Table 4.12b: Summary results of Phytoplankton diversity indices in aquatic systems around Enwhe Field during the Wet season

Diversity Indices	PW	PRoW	USPW	MSPW	DSPW	USAGIO	MSAGIO	DSAGIO	CTR
Phyto wet	Mean±STD	Mean±STD	Mean±STD	SWSD13	Mean±STD	SWSD7	SWSD12	Mean±STD	Mean±STD
Species	33±5	34±6	33±2	32	33±5	41	26	33±2	42±1
Abundance	777±187	608±254	757±220	814	763±188	354	732	757±220	398±27
Dominance_D	0.0454±0.0078	0.047±0.0117	0.0451±0.003	0.0484	0.049±0.0133	0.0339	0.0719	0.0451±0.003	0.0457±0.013
Shannon_H	3.2616±0.1542	3.2593±0.201	3.268±0.0304	3.2	3.2237±0.1981	3.52	2.894	3.268±0.0304	3.3995±0.129
Margalef	4.9096±0.975	5.2398±1.188	4.8123±0.4974	4.626	4.836±1.0184	6.815	3.79	4.8123±0.4974	6.7665±0.041
<i>PW=Proposed Wells; PRoW=Pipeline RoW; USPW = Upstream of Proposed Wells; MSPW =Midstream of Proposed Wells; DSPW = Downstream of Proposed Wells; USAGIO = Upstream of Agiogbologbo; MSAGIO = Midstream of Agiogbologbo; DSAGIO = Downstream of Agiogbologbo; CTR = Control</i>									
<i>Source: Enwhe Field Development EIA Field Data September,2016 (Wet season)</i>									

Table 4.12c: Summary results of Phytoplankton diversity indices in aquatic systems around Enwhe Field during the Dry season

	PW	PRoW	USPW	MSPW	DSPW	USAGIO	MSAGIO	DSAGIO	CTR
Diversity Indices	Mean±STD	Mean±STD	Mean±STD	SWSD1 3	Mean±STD	SWSD 7	SWSD1 2	Mean±STD	Mean±STD
Species	34±3	35±3	36±4	34	34±4	34	34	36±4	38±2
Abundance	292±70	297±55	335±65	245	299±67	220	296	335±65	272±18
Dominance_D	0.065386±0.019	0.061124±0.026	0.05776±0.002	0.0452	0.063924±0.022	0.04194	0.1247	0.05776±0.002	0.04542±0.013
Shannon_H	3.113857±0.170	3.1949±0.203	3.217333±0.092	3.273	3.139143±0.207	3.306	2.722	3.217333±0.092	3.3755±0.173
Margalef	5.816857±0.561	6.0596±0.396	6.02±0.552	5.999	5.891±0.620	6.118	5.799	6.02±0.552	6.6955±0.456
<i>PW=Proposed Wells; PRoW=Pipeline RoW; USPW = Upstream of Proposed Wells; MSPW =Midstream of Proposed Wells; DSPW = Downstream of Proposed Wells; USAGIO = Upstream of Agiobologbo; MSAGIO = Midstream of Agiobologbo; DSAGIO = Downstream of Agiobologbo; CTR = Control</i>									
Source: Enwhe Field Development EIA Field Data November,2016 (Dry season)									

Taxa:

Average number of species ranged from 26 at MSAGIO to 41 at USAGIO compared to 42 at the control during the wet season and from 34 at MSPW to 36 at DSAGIO compared to control of 38 during the dry season. Number of species was relatively higher during the dry season than wet season and at the control than the study locations.

Dominance:

Dominance ranged from 0.0339 at USAGIO to 0.0719 at MSAGIO compared to control of 0.0457 during the wet season and from 0.041 at USAGIO to 0.124 at MSAGIO compared to control of 0.045 during the dry season. Species dominance was higher during the dry season than during the wet season but no significant difference with control.

Diversity:

Shannon index measures the diversity of species in an ecosystem. Shannon Diversity ranged from 2.894 at MSAGIO to 3.52 at USAGIO compared to control of 3.399 during the wet season and from 2.772 at MSAGIO to 3.306 at USAGIO compared to control of 3.375 during the dry season. Shannon diversity was higher during the wet season than dry season was also higher at the control than study locations during the dry season.

Richness:

Margalef index measures the richness of species in an ecosystem. Margalef richness ranged from 3.79 at MSAGIO to 6.815 at USAGIO compared to control of 6.766 during the wet season and from 5.799 at MSAGIO to 6.118 at USAGIO compared to 6.695 at the control during the dry season. Margalef richness was higher during the dry season than wet season and at the control than study location.

The quality of an aquatic environment may be interpreted using the Shannon-Wiener index as follows: very good when H' is > 4 , good quality 4- 3, moderate quality 3-2, poor quality 2-1 and very poor quality <1 (Mishra *et al.*, 2010). The index ranged from 2 – 3 in the study area which is interpreted as being of moderate quality, the lowest quality was encountered at the proposed pipeline crossing midstream location near Agiobologbo while the best quality was encountered at the upstream location.

4.7.11.2 Zooplankton studies

The summary of results of Zooplankton studies is presented in Tables 4.12d and 4.12e & f for the wet and dry seasons respectively. Detailed results are presented in Appendix 4.6.11c & d. All results are presented in relation to sampling strategy to cover the Proposed Wells (PW), Pipeline Right of Way (PRoW), Existing Wells (PW) and Pipeline River Crossing (Upstream, Midstream and Downstream) locations compared to control.

Zooplankton Composition

The zooplankton was composed of Protozoa, Copepoda, Rotifera, Cladocera and Insecta with no changes in composition in the wet and dry seasons. The checklist of Zooplankton species identified in the study area and controls is presented in Table 4.12d. The percentage abundance of the zooplankton is shown in Fig. 4.6c. The zooplankton distribution followed the order: Rotifera >Copepoda >Protozoa >Insecta >Cladocera while the species distribution followed the order: Rotifera >Copepoda >Protozoa >Insecta =Cladocera during the wet season. During the dry season, the abundance followed the order: Rotifera >Copepoda >Protozoa >Insecta >Cladocera while the species distribution followed the order: Rotifera>Copepoda>Protozoa>Insecta=Cladocera. Rotifera was the most abundant and dominant species during the both seasons followed by the Copepoda while Cladocera and Insecta were the least abundant and dominant. The dominance of Zooplankton by copepod and rotifers is common in Nigerian waters (RPI/NNPC, 1985)

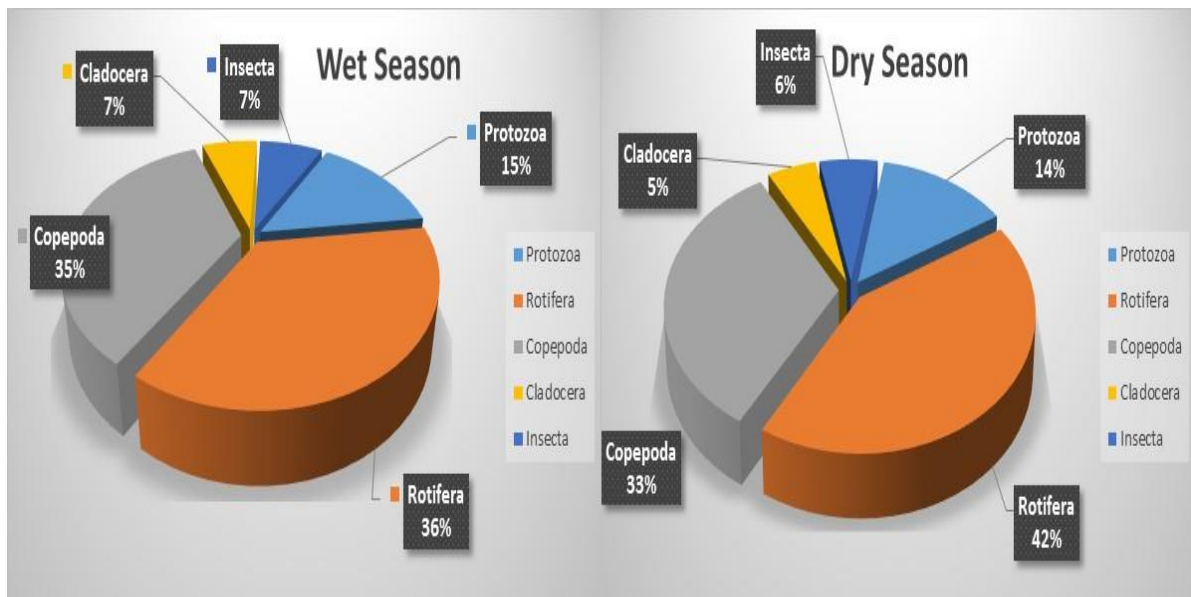


Fig. 4.6c: Relative abundance of Zooplankton in the study area

Table 4.12d: Checklist of Zooplankton in aquatic systems around Enwhe Field

S/N	Wet Season					Dry Season				
	Protozoa	Rotifera	Copepoda	Cladocera	Insecta	Protozoa	Rotifera	Copepoda	Cladocera	Insecta
1										
2	<i>Coleps sp.</i>	<i>Brachionussp</i>	<i>Cyclops sp.</i>	<i>Daphnia pulex</i>	<i>Chaoborus sp.</i>	<i>Coleps sp.</i>	<i>Brachionussp</i>	<i>Cyclops sp.</i>	<i>Daphnia pulex</i>	<i>Chaoborus sp.</i>
3	<i>Loxodessp</i>	<i>Stentor sp.</i>	<i>Limnocalanus macrurus</i>	<i>Daphnia barbata</i>	<i>Cypris sp.</i>	<i>Loxodessp</i>	<i>Stentor sp.</i>	<i>Limnocalanus macrurus</i>	<i>Daphnia barbata</i>	<i>Cypris sp.</i>
4	<i>Sarcodina sp</i>	<i>Asphlanchiabrightwelli</i>	<i>Macrocyclopsa ter</i>			<i>Sarcodina sp</i>	<i>Asphlanchiabrightwelli</i>	<i>Macrocyclopsa ter</i>		
5	<i>Urocentrum sp.</i>	<i>Philodina sp.</i>	Naplius I of copepoda			<i>Urocentrum sp.</i>	<i>Philodina sp.</i>	Naplius I of copepoda		
6	<i>Vorticella sp.</i>	<i>Rotaria sp.</i>	<i>Senecellacaloidea</i>			<i>Vorticella sp.</i>	<i>Rotaria sp.</i>	<i>Senecellacaloidea</i>		
7		<i>Monostylasp</i>	<i>Moina</i>				<i>Monostylasp</i>	<i>Moina</i>		
8		<i>Polyarthra</i>	<i>Thermocyclops neglectus</i>				<i>Polyarthra</i>	<i>Thermocyclops neglectus</i>		
9		<i>Kerratela</i>	<i>Tropodiatom ussp</i>				<i>Kerratela</i>	<i>Tropodiatom ussp</i>		
10		<i>Chilodonella</i>	<i>Mesocyclops</i>				<i>Chilodonella</i>	<i>Mesocyclops</i>		
11		<i>Filiniasp</i>					<i>Filiniasp</i>			
Density/l	572	1402	1370	256	294	178	553	435	67	79
% Abundance	14.36	35.19	34.39	6.43	9.65	12.75	40.61	33.16	4.80	7.73
Abundance order	Rotifera>Copepoda>Protozoa>Insecta>Cladocera					Rotifera>Copepoda>Protozoa>Insecta>Cladocera				
Species order	Rotifera>Copepoda>Protozoa>Insecta=Cladocera					Rotifera>Copepoda>Protozoa>Insecta=Cladocera				

Table 4.12e: Summary results of Zooplankton diversity indices in aquatic systems around Enwhe Field during the Dry season

Diversity Indices	PW	PRoW	USPW	MSPW	DSPW	USAGIO	MSAGIO	DSAGIO	CTR
	Mean±STD	Mean±STD	Mean±STD	SWSD13	Mean±STD	SWSD7	SWSD12	Mean±STD	Mean±STD
Species	21±11	21±3	20±3	24	21±2	23	24	20±3	
Abundance	237±126	237±36	239±12	292	220±47	276	292	239±12	
Dominance_D	0.078819±0.438	0.08866±0.024	0.094497±0.013	0.06704	0.07596±0.022	0.08283	0.06704	0.094497±0.013	
Shannon_H	2.773143±0.206	2.6993±0.2049	2.630667±0.084	2.866	2.777714±0.205	2.716	2.866	2.630667±0.085	
Margalef	3.738714±0.352	3.6759±0.457	3.466±0.516	4.052	3.692571±0.344	3.914	4.052	3.466±0.516	

PW=Proposed Wells; PRoW=Pipeline RoW; USPW = Upstream of Proposed Wells; MSPW =Midstream of Proposed Wells; DSPW = Downstream of Proposed Wells; USAGIO = Upstream of Agiobologbo; MSAGIO = Midstream of Agiobologbo; DSAGIO = Downstream of Agiobologbo; CTR = Control

Source: Enwhe Field Development EIA Field Data September,2016 (Wet season)

Table 4.12f: Summary results of Zooplankton diversity indices in aquatic systems around Enwhe Field during the Dry season

Diversity Indices	PW	PRoW	USPW	MSPW	DSPW	USAGIO	MSAGIO	DSAGIO	CTR
	Mean±STD	Mean±STD	Mean±STD	SWSD13	Mean±STD	SWSD7	SWSD12	Mean±STD	Mean±STD
Species	26±3	22±3	20±2	27	23±3	24	21	20±2	
Abundance	80±18	82±13	75±13	105	73±15	85	74	75±13	
Dominance_D	0.074611±0.016	0.067817±0.009	0.078343±0.005	0.0663	0.076926±0.016	0.05689	0.07378	0.078343±0.005	
Shannon_H	2.858429±0.167	2.8755±0.120	2.723333±0.083	2.977	2.819286±0.169	2.993	2.859	2.723333±0.083	
Margalef	5.164571±0.516	4.8369±0.483	4.330333±0.417	5.587	5.026714±0.514	5.177	4.647	4.330333±0.417	

PW=Proposed Wells; PRoW=Pipeline RoW; USPW = Upstream of Proposed Wells; MSPW =Midstream of Proposed Wells; DSPW = Downstream of Proposed Wells; USAGIO = Upstream of Agiobologbo; MSAGIO = Midstream of Agiobologbo; DSAGIO = Downstream of Agiobologbo; CTR = Control

Source: Enwhe Field Development EIA Field Data November,2016 (Dry season)

The spatio-seasonal distribution of the zooplankton is shown in Fig. 4.6d. Zooplankton abundance was significantly higher during the wet than dry season for all species. Most studies report the opposite trend where dry season shows higher levels of zooplankton abundance and species diversity than the wet season (Akpan, 1993). The trend observed in this study may be attributed to the seasonal distribution of phytoplankton since the zooplankton depends on phytoplankton for food. It is also possible that some species were washed into the river from the catchment during rains leading to higher abundance in the wet season

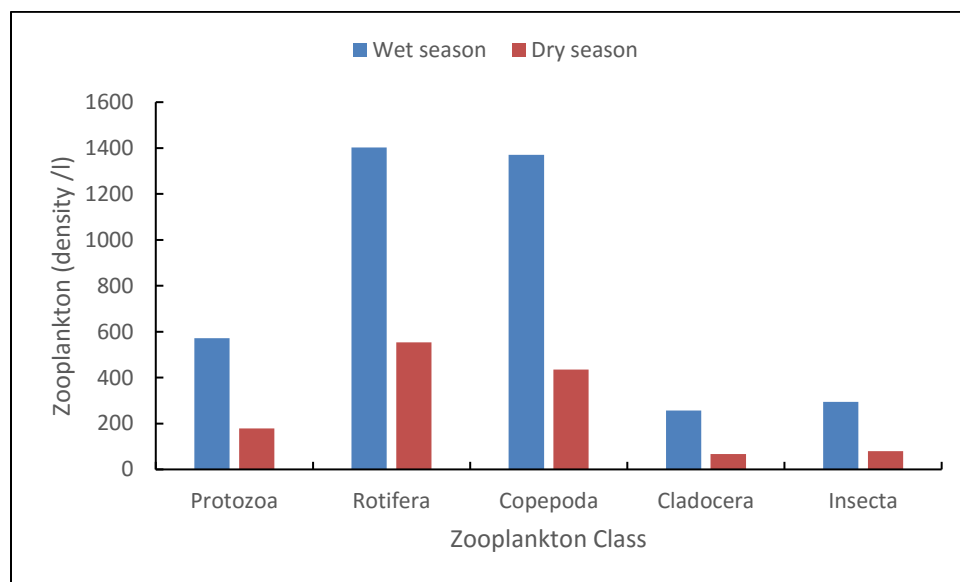


Fig. 4.6d: Spatial and Seasonal variation in Zooplankton abundance at the study location

Zooplankton Diversity

Diversity measures have important applications in aquatic ecosystems studies. In environmental monitoring, the adverse effects of pollution are known to result in the reduction of diversity or changes in the composition of species abundance. Tables 4.12e and 4.12f show the diversity indices for the zooplankton from the study area compared to control.

Taxa:

Average number of species ranged from 20 at USPW to 24 at MSPW and MSAGIO during the wet season and from 20 at USPW to 27 at MSPW during the dry season. Number of species was relatively higher during the dry season than wet season.

Dominance:

Dominance ranged from 0.067 at MSPW and MSAGIO to 0.094 at USPW and DSAGIO during the wet season and from 0.0569 at USAGIO to 0.07834 at USPW during the dry season. Species dominance was higher during the wet season than during the dry season.

Diversity:

Shannon index measures the diversity of species in an ecosystem. Shannon Diversity ranged from 2.6306 at USPW and DSAGIO to 2.866 at MSPW during the wet season and from 2.7233 at USPW and DSAGIO to 2.993 at USAGIO during the dry season. Shannon diversity was higher during the dry season than wet season.

Richness:

Margalef index measures the richness of species in an ecosystem. Margalef richness ranged from 3.466 at USPW and DSAGIO to 4.052 at MSPW and MSAGIO during the wet season and from 4.330 at USPW and DSAGIO to 5.587 at MSPW during the dry season. Margalef richness was higher during the dry season than wet season. The quality of an aquatic environment may be interpreted using the Shannon-Wiener index as follows: very good when H' is > 4 , good quality 4- 3, moderate quality 3-2, poor quality 2-1 and very poor quality <1 (Ashutosh Mishra *et al.*, 2010). The index ranged from 2 – 3 in the study area which is interpreted as being of moderate quality at all locations.

4.7.11.3 Macroenthic studies

The summary of results of Macroenthic studies is presented in Tables 4.12g and 4.6g and h for the wet and dry seasons respectively. Detailed results are presented in Appendix 4.6.11e & f. All results are presented in relation to sampling strategy to cover the Proposed Wells (PW), Pipeline Right of Way (PRoW), Existing Wells (PW) and Pipeline River Crossing (Upstream, Midstream and Downstream) locations compared to control.

Macroenthos Composition

The macroenthos was composed of Crustacea, Annelida, Plecoptera, Diptera (Insecta) and Coleoptera with no changes in composition in the wet and dry seasons. The checklist of macroenthos species identified in the study area and controls is presented in Table 4.12g. The percentage abundance of the macroenthos is shown in Fig. 4.6a. The Macroenthos distribution followed the order: Crustacea $>$ Anelida $>$ Plecoptera $>$ Diptera $>$ Coleoptera while the species distribution followed the order: Anelida $>$ Diptera = Plecoptera $>$ Coleoptera = Crustacea during the wet season. During the dry season, the abundance followed the order: Diptera $>$ Anelida $>$ Plecoptera $>$ Crustacea $>$ Coleoptera while the species distribution followed the order: Anelida $>$ Diptera = Plecoptera $>$ Coleoptera = Crustacea. Crustacea (34%) was the most abundant during the wet season but during the dry season the community was dominated by Insecta (Diptera).

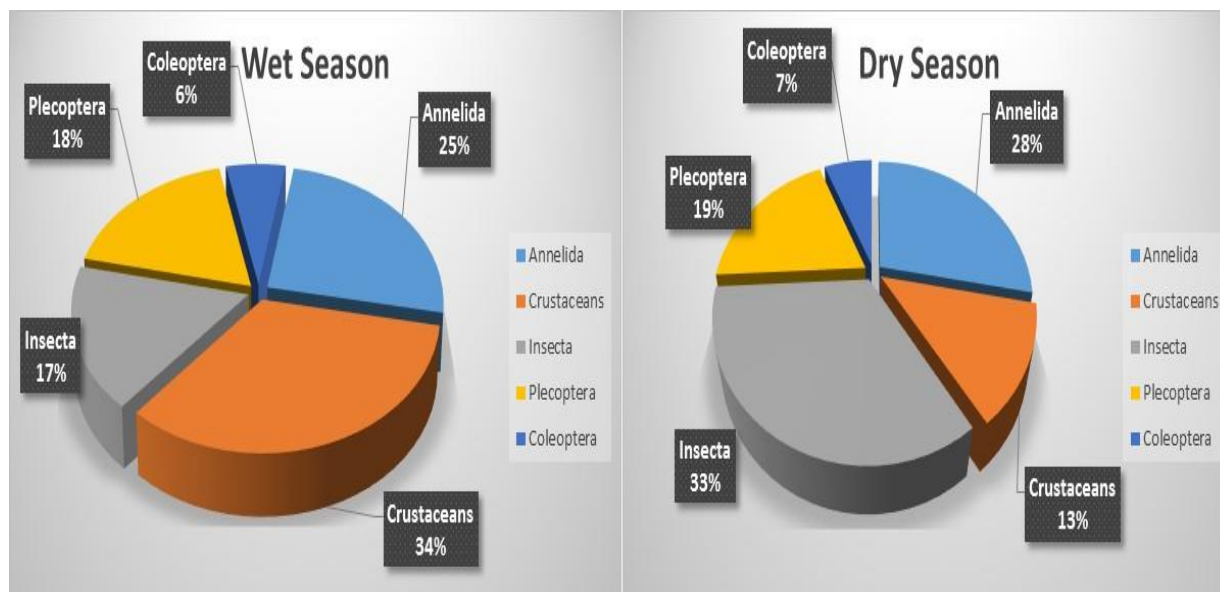


Fig. 4.6a: Relative Abundance of Macrobenthic organisms in the study area during wet and dry seasons

The spatio-seasonal distribution of the macrobenthic fauna is shown in Fig. 4.6b. Macrobenthos abundance was significantly higher during the wet than dry season for all species. The trend observed in this study may be attributed to increased availability of organic substrate for food. The wet season was characterized by higher levels of silt and clay in sediment (Section 4.6.4-sediment texture). According to Wells and Conkwright (1999) the clay content of sediments is a very good indicator of minimum values for carbon content (food source for benthos). It is also possible that some species were washed into the river from the catchment during rains leading to higher abundance in the wet season

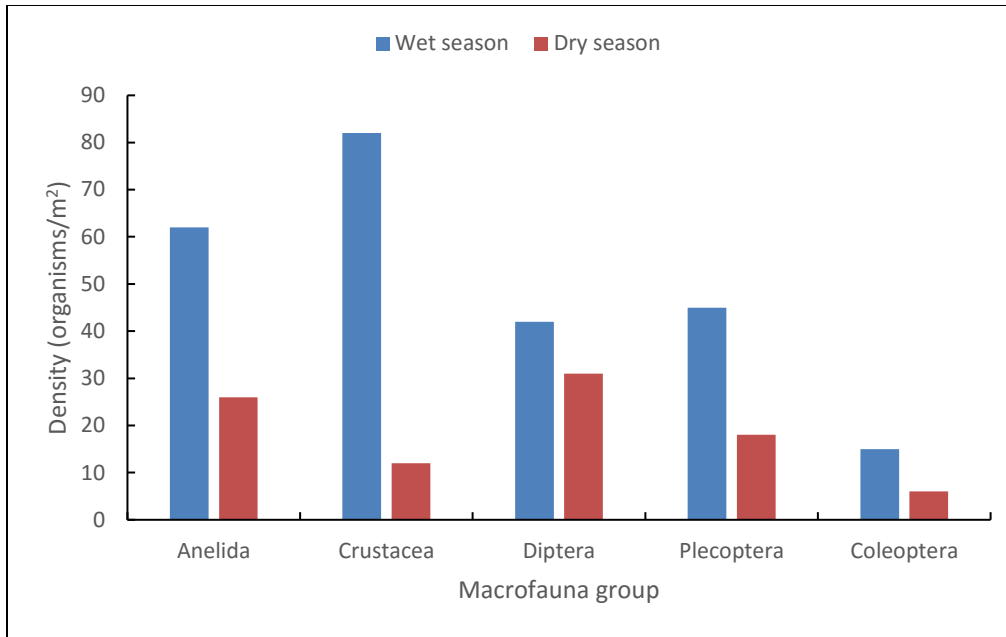


Fig. 4.6b: Spatial and Seasonal variation in Macrobenthos abundance at the study location

Macrobenthos Diversity

Tables 4.12g & h show the diversity indices for the macrobenthos from the study area compared to control.

Taxa:

Average number of species ranged from 6 at USPW and DSAGIO to 11 at MSPW compared to control of 12 during the wet season and from 4 at MSAGIO to 8 at USAGIO compared to 6 at control during the dry season. Number of species was relatively higher during the wet season than dry season with the control showing the highest species number during the wet season.

Dominance:

Dominance ranged from 0.097 at MSPW to 0.2559 at USPW and DSAGIO compared to control of 0.0979 during the wet season and from 0.125 at USAGIO to 0.1761 at PRow compared to control of 0.1825 during the dry season. Species dominance was higher during the wet season than during the dry season.

Diversity:

Shannon index measures the diversity of species in an ecosystem. Shannon Diversity ranged from 1.604 at USPW and DSAGIO to 2.369 at MSPW compared to 2.407 at the control during the wet season and from 1.386 at MSAGIO to 2.079 at USAGIO compared to 1.7535 at the control during the dry season. Shannon diversity was relatively higher during the wet season than dry season. The Shannon diversity index (Mean:1.386-2.407) however points to a greater level of stress in the

benthic environment. This may be linked to the low levels of organic food source in the sediment particularly in the dry season when the sediments are dominated by sand.

Richness:

Margalef index measures the richness of species in an ecosystem. Margalef richness ranged from 2.415 at USAGIO to 4.024 at MSPW during the wet season compared to 3.921 at the control and from 2.164 at MSAGIO to 3.366 at USAGIO compared to 2.657 during the dry season. Margalef richness was relatively higher during the wet season than dry season.

Table 4.12g: Checklist of Macrobenthic organisms in aquatic systems around Enwhe Field

Wet season						Dry Season				
S/N	Annelida	Arthropoda		Plecoptera	Coleoptera	Annelida	Arthropoda		Plecoptera	Coleoptera
		Crustaceans	Insecta				Crustaceans	Insecta		
			Diptera					Diptera		
1	<i>Neries sp.</i>	<i>Cardisom asp.</i>	<i>Chironomus</i> (larva /pupa)	<i>Ephemera</i>	<i>Dytiscus</i>	<i>Neries sp.</i>	<i>Cardisom asp.</i>	<i>Chironomus</i> (larva /pupa)	<i>Ephemera</i>	<i>Dytiscus</i>
2	<i>Brachiura</i>		<i>Pentanuera</i>	<i>Gyrinus</i> ssp.		<i>Brachiura</i>		<i>Pentanuera</i>	<i>Gyrinus</i> ssp.	
3	<i>Chaetogaster</i>		<i>Anopheles</i> larvae	Odonata nymphs		<i>Chaetogaster</i>		<i>Anopheles</i> larvae	Odonata nymphs	
4	<i>Stylaria</i>		<i>Smilium</i> larvae	Water boatman		<i>Stylaria</i>		<i>Smilium</i> larvae	Water boatman	
5	<i>Nais</i>					<i>Nais</i>				
Density/ m ²	62	82	42	45	15	26	12	31	18	6
%Abundance	23.49	31.06	15.91	17.05	5.68	20.97	9.68	25	14.52	4.84
Abundance order	Crustacea>Anelida> Plecoptera > Diptera >Coleoptera					Diptera >Anelida> Plecoptera > Crustacea >Coleoptera				
Species order	Anelida> Diptera= Plecoptera>Coleoptera= Crustacea					Anelida> Diptera= Plecoptera>Coleoptera= Crustacea				

Table 4.12h: Summary results of Macrobenthic diversity indices in aquatic systems around Enwhe Field during the Wet season

	PW	PRoW	USPW	MSPW	DSPW	USAGIO	MSAGIO	DSAGIO	CTR
Diversity Indices	Mean±STD	Mean±STD	Mean±STD	SWSD 13	Mean±STD	SWSD 7	SWSD 12	Mean±STD	Mean±STD
Species	9±2	7±2	6±2	11	8±2	7	8	6±2	12±1.41
Abundance	15±2	12±3	12±2	12	15±4	12	11	12±3	17±1
Dominance_D	0.209474±0.067	0.224142±0.076	0.255967±0.105	0.09722	0.214986±0.057	0.1944	0.1901	0.255967±0.105	0.097955±0.016
Shannon_H	1.912286±0.245	1.7599±0.307	1.604333±0.390	2.369	1.865714±0.159	1.792	1.894	1.604333±0.390	2.407±0.141
Margalef	3.031429±0.608	2.6139±0.685	2.238±0.858	4.024	2.911714±0.439	2.415	2.919	2.238±0.858	3.921±0.444
<i>PW=Proposed Wells; PRoW=Pipeline RoW; USPW = Upstream of Proposed Wells; MSPW =Midstream of Proposed Wells; DSPW = Downstream of Proposed Wells; USAGIO = Upstream of Agiobologbo; MSAGIO = Midstream of Agiobologbo; DSAGIO = Downstream of Agiobologbo; CTR = Control</i>									
Source: Enwhe Field Development EIA Field Data September,2016 (Wet season)									

Table 4.12i: Summary results of Macrobenthic diversity indices in aquatic systems around Enwhe Field during the Dry season

	PW	PRoW	USPW	MSPW	DSPW	USAGIO	MSAGIO	DSAGIO	CTR
Diversity Indices	Mean±STD	Mean±STD	Mean±STD	SWSD1 3	Mean±STD	SWSD 7	SWSD1 2	Mean±STD	Mean±STD
Species	6±1	6±1	6±0	6	6±1	8	4	6±0	6±1
Abundance	7±1	7±1	6±1	7	9±2	8	4	6±1	7±1
Dominance_D	0.172386±0.035	0.17611±0.031	0.172367±0.010	0.1837	0.168471±0.035	0.125	0.25	0.172367±0.010	0.18255±0.056
Shannon_H	1.800714±0.210	1.7752±0.167	1.777333±0.025	1.748	1.823286±0.212	2.079	1.386	1.777333±0.025	1.7535±0.272
Margalef	2.770571±0.444	2.7354±0.297	2.717±0.128	2.569	2.815714±0.436	3.366	2.164	2.717±0.128	2.6575±0.602
<i>PW=Proposed Wells; PRoW=Pipeline RoW; USPW = Upstream of Proposed Wells; MSPW =Midstream of Proposed Wells; DSPW = Downstream of Proposed Wells; USAGIO = Upstream of Agiobologbo; MSAGIO = Midstream of Agiobologbo; DSAGIO = Downstream of Agiobologbo; CTR = Control</i>									
Source: Enwhe Field Development EIA Field Data November,2016 (Dry season)									

4.7.11.3: Fisheries

The finfish species in river Orashi and river Nun in Enwhe consisted of 11 Families including, Hepsitidae, Characidae, Channidae, Ariidae, Centropomidae, Carangidae, Anabantidae, Bagridae, Cichlidae, Clariidae and Citharinidae. (Table 4.13) The Characidae were the highest in species abundance, followed by the Cichlidae, Citharinidae and Clariidae. The fish species in the Family Clariidae were *Clarias gariepinus*, *C. anguillaries* and *C. isheriensis*. The Family Cichlidae was represented by *Hemichromis bimaculatus*, *H. fasciatus*, *Pelmatochromis guentheri*, *Tilapia zillii*, *Sarotherodon galilaeus*, *Tilapia heudelotii*, *T. mariae* and *Oreochromis niloticus*. Bagriidae was represented by *Bagrus bayad*, *B. filamentosus*, *Clarotes lanticeps* and *C. macrophalus*. The Family Characidae was represented by *Hydrocynus brevis*, *H. lineatus*, *H. forskalii*, *Alestes nurse*, *A. baremoze*, *A. longipinnis*, *Micralestes acutidens*. Citharinidae was represented by *Citharinus latus* and *C. distichodus*. Anabantidae was represented by *Ctenopoma kingsleye* and *C. petherisi*, Carangidae, Ariidae, Hepsitidae and Centropomidae were represented by one species each. There was no significant difference in fishes caught during the rainy season and dry season.

There was overexploitation of the fisheries resources because very many individuals are involved in fishing in the area. Artisanal fisheries or small scale fishers dominate the fishery of the study area. They operate in dug-out wooden canoes which may or may not be motorized. Fishing gears are largely made of long setlines, circling nets and seine nets of different mesh sizes varying between ½", 1", 1½", 2", 2½" and 3" (1.0mm to 5.0mm). Gears measure 6 - 12m in length and 2-4 meters in width. Nets are manually operated. They are set and allowed to stay for up to one hour before they are removed with the catch. The catch per unit effort in this study area indicate that there was overexploitation of the fisheries.

Table 4.13: List of fish species in the study area

Family/Species	Abundance Rating	
	Wet Season	Dry Season
FAMILY HEPSETIDAE		
<i>Hepsetusodoe</i>	1	0
FAMILY CHANNIDAE		
<i>Ophiocephalusobscurus</i>	3	1
<i>O. africanus</i>	4	3
FAMILY CHARACIDAE		
<i>Hydrocynusbrevis</i>	2	1
<i>H. lineatus</i>	4	1
<i>H. forskalii</i>	2	1
<i>Alestes nurse</i>	1	3
<i>A. brevis</i>	5	3
<i>A. dentex</i>	1	2
<i>A. baremoze</i>	2	2
<i>A. longipinnis</i>	2	1
<i>Micralestesacutidens</i>	3	2
FAMILY ARIIDAE		
<i>Arius heudelotti</i>	2	1
FAMILY CARANGIDAE		
<i>Trachinotusgoreensis</i>	0	2
FAMILY CENTROPOMIDAE		
<i>Latesniloticus</i>	1	2
FAMILY ANABANTIDAE		
<i>Ctenopomakingsleyae</i>	2	1
<i>C. petherici</i>	1	2
FAMILY BAGRIDAE		
<i>Bagrusbayad</i>	1	2
<i>B. filamentosus</i>	1	1
<i>Claroteslaticeps</i>	1	1
<i>C. macrocephalus</i>	2	1
<i>Parauchenoglanisansorgii</i>	1	3
FAMILY CICHLIDAE		
<i>Hemichromisbimaculatus</i>	2	1
<i>H. fasciatus</i>	2	0
<i>Pelmatochromisguentheri</i>	1	1
<i>Tilapia zillii</i>	2	1
<i>Sarotherodongalilaeus</i>	1	1
<i>Tilapia heudelotii</i>	3	3
<i>T. mariae</i>	1	2
<i>Oreochromis niloticus</i>	1	2
FAMILY CLARIIDAE		

Family/Species	Abundance Rating	
<i>Clariasgariepinus</i>	2	0
<i>C.anguillaris</i> ,	1	1
<i>C.isheriensis</i>	0	0
FAMILY CITHARINIDAE		
<i>D. rostartus</i> (Gunther)	1	1
<i>Citarinuslatus</i> (Muller &Froschei)	2	2
<i>C. distichodus</i> (Pelligrini)	1	1

Source: Michhary & Sons Nigeria Limited, Enwhe Field EIA (Wet Season Sept., 2016. & Dry Season: Nov., 2016)

Fish catch in the Niger Delta as in many other parts of the country has been on the decline. Although the local people have often implicated environmental pollution resulting from oil and gas exploitation in the area it is obvious that over fishing has played a role also. The population of fisher folks in the old Rivers State (now River and Bayelsa States) is approximately 32% that of the entire country (River State statistical year 1994). In 1985 the combined figure for full-time fisher men in Rivers/Bayelsa state was 23,590 (Sikoki and Otobotekere, 1999).

4.7.12: Social Profile

4.7.12.1: Stakeholder Communities and Brief Community History

The twenty-four (24) stakeholder communities of the Enwhe Field Development Project (FDP) covered in this Report are drawn from 5 Clans across Bayelsa and Rivers States. The clans covered in Rivers State are: Emughan in Abua/Odual Local Government Area; and Igbuduya and Engenni in Ahoada West Local Government Area. Those in Bayelsa State are: Gbaran and Epie/Atissa. The details of the stakeholder communities in each Clan, Local Government Area, and State are furnished in Table 4.14a.

Table 4.14a: Stakeholder Communities in Enwhe FDA

SN	State	Local Government Area	Clan	Community
1	Rivers State	Abua/ Odua LGA	Emughan	Aminigboko
2				Owerewere
3				Emesu
4				Okoboh
5				Emabu
6				Obarany
7				Egunughan
8		Ahoada West	Igbuduya	Obodhi
9				Ogbologbolo
10				Ogbede
11				Odieke Ugbobi
12				Odigwe
13			Engenni	Ogbogolo (Ogbogolo, Opu Ogbogolo, Kala Ogbogolo, Egboama Ogbogolo)
14				Akiogbologbo
15				Ikodi Engenei
16				Okarki
17				Kunushia
18	Bayelsa State	Yenagoa LGA	Gbaran	Okolobiri
19				Obunagha
20		Epie	Okutukutu	
21			Agudama-Epie	
22			Kumboama	
23			Akenfa	

Source: Field Study, 2016.

Almost all the communities in the Enwhe Field Development Project trace their ancestry to the Ancient Benin Empire in present day Edo State of Nigeria. This is corroborated by Alagoa (1999) and Sorgwe (1990). According to oral history, at about 1542AD, an assassination attempt was said to have been planned on the Oba Awuarre of the Ancient Benin Empire, who was reportedly inhuman to his subjects. The failed plot led to a great exodus of people from the then Benin Kingdom for fear of being killed.

For example, the Ekpeye and Ogba peoples of Rivers state are said to be sons of the same father but different mothers. They migrated from the Ancient Benin Empire. They moved southwards along the River Niger eventually arriving and settling along the Orashi River in current day Ubie.

The original families that arrived and settled in present day Ekpeye Clan were: Imaji, Achi, Agolo, Uzhi, Ishikoloko, Ediwulu, and Akpa. Aminigboko, Owerewere, Emesu, Emunughan, Okoboh, Emabu and Obarany communities were reported to be a sub-clan of the Ekpeye Clan while the Igbuduya Clan is also a sub-clan of the larger Ekpeye Clan. Akor the ancestor of Igbuduya is said to be a descendant of Ekpeye.

The Engenni people also trace their ancestry to the Ancient Benin Empire, their language being classified as being of the Edoid category. It is related that on their migratory journey, they first settled in present day Isoko and later settled at a place called Ewurebe. Though now extinct, the Ewurebe is related to have been situated at a location somewhere between present day Biseni and Engenni. From there the migrants dispersed and established other communities such as Okilogua, Okpanikio, Nyenegile, and Eliabi (Akinima) before finally settling at the present location of Engenni. The Engenni people claim to have historical relationship with the peoples of Degema, Usokun, Obonoma, Abua, Kula and Bille in Rivers State; and the Ogbia, Zarama, and Epie/Atissa peoples in Bayelsa State.

4.7.12.2: Religion, Customs, Belief Systems and Cultural Heritage

Like most communities in the Niger Delta, majority of the people of the communities studied are adherents of the Christian Religion. About 85% of the people interviewed said they are Christians while the rest are either traditional religionists or atheists. Though the traditional religion worshippers are fewer in number, they command some influence because they are the preservers and custodians of the people's customs and traditions. This is particularly true with respect to the priests of the native shrines and deities. Common among the communities in the Enwhe FDA is the belief in totems and sacred places: shrines, trees, animals, streams, forests, etc. The general belief and custom among the people of these communities is that such sacred places and the deities, if regularly appeased, usually protect either the entire people of the community or families/quarters responsible for their worship.

The communities in the Enwhe FDA reportedly have a number of such shrines, sacred grounds, etc. which could be of interest in further engagement in the course of project development and operation. Detailed information on the said shrines, sacred grounds and other related sites are given in Table 4.14b.

Table 4.14b: List of Shrines, Sacred Grounds and Related Sites in the Enwhe FDP

Clan/ Communities	Sacred/ Forbidden Areas	Lakes/ Creeks	Remarks
Ekpeye clan – Aminigboko Owerewere Emesu Egunughan Okoboh, Emabu & Obarany is not part of the study area.	<ul style="list-style-type: none"> ▪ Akeema Deity for Ekpeye clan in general ▪ Families have deities such as:- Obobila (Akiro family), Okomako Ogbolo (Ogbolo), Ogosi Aminigboko & Eebom Isakah(Atian),Ookeku Okwuo (Ukwuo). ▪ Akiema Owerewere Deity, Ekpaar Omughu Deity (found only in Omughu Family), Egbukele shrine, Enuneghen sacred forest (Ebocha forest), Okpa Izoghi (only in Izoghi family), Odu Deity, Ekpaar Omughy (for Omughy family), Emuneghan ▪ Akeema shrine is for all Ekpeye clan and located within the community, Sacred fish ponds in Emesu are Ogakimo & Oboomdum ponds. Oghogh Odu is also a sacred place. ▪ Akeema & Akari Kposi community shrines 	<ul style="list-style-type: none"> ▪ Odu Water Deity ▪ Oordu Ophiye sacred lake belongs to Akiro family, Aminigboko. Annual worship is in May/June. ▪ Odu swamp ▪ Orashi River, Orsbor Lake ▪ Uboso Iluan lake 	<ul style="list-style-type: none"> ▪ At Erugaken Festival, movements are restricted the night proceeding the festival day which is celebrated only by heads of each community in Emughan sub-clan of Ekpeye Clan in Aminigboko. ▪ The Owerewere Egbukele is worshipped between the months of April and June annually. The Ekpaar Omughu and Okpa Izoghi shrines are found only in Omughu and Izoghi families respectively in Owerewere community. Of all the sacred water bodies in Owerewere, it is in only Odu pond that crocodiles and alligators are permitted to be killed within the community. ▪ Fishing in Orsbor Lake is every 10 years b/w April – June. Community derive enormous income mining sand from Orashi River. ▪ Uboso Lake host fishing & boat regatta every 7 years on the 7th of April. Other festivals in Egunughan are Oboghotu & OgboghOoke where Ekine Arughu masquerades & Adianagh Kokpan is observed in the bush/forest.
Igbuduya clan Obodi	<ul style="list-style-type: none"> ▪ Shrines are Agbali, Ogbuleke, Ishakpa. These have cultural significance. 	<ul style="list-style-type: none"> ▪ Lakes are Ilo, Azere, Udereho and Owuilo 	<ul style="list-style-type: none"> ▪ Appeasement for violations of <ul style="list-style-type: none"> ○ Ogbuleke is ram, gin, etc. ○ Agbali is Cow, gin, etc.

Clan/ Communities	Sacred/ Forbidden Areas	Lakes/ Creeks	Remarks
Ogbologbolo Ogbede	<ul style="list-style-type: none"> ▪ Igba, Inalegbe & Ibazu are deities in Ogbologbolo, where Igba/Inalegbe share abode. Izu is a scared day. ▪ Scared shrines are Ilobeze, Ugbulokpu & Udegbukele; Eke & Nkwo are forbidden days for farm work or entry into the forest/bush for any form of farming. 	<ul style="list-style-type: none"> ▪ 	<ul style="list-style-type: none"> ▪ *All the deities in Obodi serve as arbitrator & protector & can be approached for fertility. Rate of poverty is high here because only 2 days is dedicated for farming. ▪ Violation of Izu day attracts appeasement in Ogbologbolo. ▪ Fishing is conducted every 7years. ▪ Scared Shrines are Ilobeze for safety of community and fertility; Ugbulokpu, Udegbukele (Items used for appeasement are white ram, yam, gin, kola-nut and money to be determined by the chief priest).
Odoroogboji clan – Odieke Ugbobi	<ul style="list-style-type: none"> ▪ Osulu – Ukpo (Osukpo), Ogidi & Kelegbu sacred shrines. Eke is a scared day. 	<ul style="list-style-type: none"> ▪ Osu lake; Family swamps are Ude – Ado, Ogbuliobi, Ugbuliu Asedi & Ubalibo. 	<ul style="list-style-type: none"> ▪ Only initiates are permitted to sacrifice at Osulu-Ukpo shrine every 7years. Sacrifice with items – white goat, fowl, ram, cow, gin & plantain is required before fishing takes place in the lake. Appeasement items for violations are cow, white goat, plantain, yams and gin. ▪ Swamps belong to respective families in Odieke Ugbobi.
Ogbogolo clan- Opu Ogbogolo Kala Ogbogolo Egboama	<ul style="list-style-type: none"> ▪ Ogurua Edum cemetery, Otobo (god of the land) ▪ 	<ul style="list-style-type: none"> ▪ Ologio Ewenu Creek, Iguba lake shrine, Agu-Ohe ▪ *These lakes have cultural and natural endowments significance for the community. 	<ul style="list-style-type: none"> ▪ Cemetery is scared ground ▪ There is no restriction to access the forest but Ologio serves as shrine with a designated spot for worship; Otobo is god of protection for Ogbogolo clan. ▪ Before entry into the sacred grounds/forests, sacrifices and rituals involving witch doctors or priests are performed to avert repercussions.

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Clan/ Communities	Sacred/ Forbidden Areas	Lakes/ Creeks	Remarks
Engenei clan – Akiogbologbo Ikodi Okarki Kunusha	<ul style="list-style-type: none"> ▪ Igbini swamp forest, Ashio Ogwe forest, Agu shrine, Awu shrine ▪ Young Solomon’s shrine, Eti Uzi cemetery & Ewayi Ovum Abia ▪ Orakata is main community shrine; Baptist & Adventist Church Cemeteries ▪ Iladuede shrine, Eti-Uzi cemetery, Igbedu shrine 	<ul style="list-style-type: none"> ▪ Achifiam Creek, Okpobiri Lake, Awu Lake, Ibori Lake, Ipurabam swamp, Ikinagi Lake & Onuyi Creek ▪ Lakes - Edem, Ashom, Oyori, Enuyori, Elake, Azor, Ewu, Enu Ofiam, Ekuruman & Ewayi Ovum Abia ▪ Okpopiri Lake - worship is carried out b/w 7-14years; Ivuii Lake – worshipped every 3 or 4years ▪ Edem lake, Abaifayi lake, Uderehuo lake, Onodu swamp & Ibedi swamp 	<ul style="list-style-type: none"> ▪ Agu deity protects Akiogbologbo community ▪ These lakes have significant cultural & natural endowments for the community. Harvested yearly; Edem Lake serves three communities. Harvested every 3 years. ▪ Orakata deity is believed to protect and grant fertility. ▪ Iladuede is a forbidden forest which harbours Iladuede shrine where subjects go for litigation to press for violated rights. However, both deities provide protection for the community. ▪ *These lakes have cultural and natural endowments significance for the community. Sacrificed for bumper harvest.
<ul style="list-style-type: none"> ▪ Gbaran clan – ▪ Okolobiri ▪ Obunagha ▪ Oboloma 	<ul style="list-style-type: none"> ▪ Ekemgbai is a scared day in the entire Gbaran Clan ▪ Egbesu shrine ▪ No sacred place any longer. ▪ Agba shrine 	<ul style="list-style-type: none"> ▪ All rivers & lakes represent a deity in Okolobiri community. 	<ul style="list-style-type: none"> ▪ Farming and entry into the forest/bush is forbidden as it attracts fine after they violator must have been interrogated. Whereby the violated is plagued, the Chief Priest is consulted for appeasement materials / items. ▪ Violation is not taken kindly. It attracts the rebuilding of shrine and the custodian is consulted

Clan/ Communities	Sacred/ Forbidden Areas	Lakes/ Creeks	Remarks
<ul style="list-style-type: none"> ▪ Kumbo Ama 			for needed materials and items of appeasement in Okolobiri.

Source: Field Survey, 2016

4.7.12.3: Political Structure and Governance

Historically, most communities in Izon land had been administered by an Ama-Okosuwei (the most elderly) or an Amanana-Owei. Gerontocracy was therefore the basis of rulership prior to the colonial era up until Nigeria's independence. Executive, legislative and judicial functions were vested in the Ama-Okosuwei or Amanana-Owei and a cabinet constituted of family or compound heads or elders. In some cases, the Ama-Okosuwei or Amanana-Owei was also the chief priest of the community deity, as well as custodian of the indigenous culture and tradition of the people (Okaba, 1999). Together, this group perform the traditional duties of settling quarrels and disagreements within the community while the day-to-day administration of the communities is partially delegated to a Community Development Committee (CDC), which is a government-recognized body with an elected Chairman, Secretary, etc. The CDC is supported by the Youth Group whose functions include sanitation, labour and security affairs or other functions as may be delegated by the Paramount Ruler and/or the CDC.

Under the CDC are the Women and Youth Associations or Groups which were formerly organized on age-grade basis, as well as other community-based organisations such as unions, clubs, religious bodies, cooperatives, etc. Below this level are the individual members and non-members of the community. This system of governance describes the situation with respect to the Communities in the Gbaran Clan and to a large extent that of the Epie, Engenni, Emughan, and Igbuduya Clans. The major difference is in the title of the Paramount Ruler. Whereas in the Gbaran Clan, the Paramount Ruler is called either an Ama-Okosuwei or Amananaowei, the same position and function is known by different names in the other clans. For example, it is called Obanekien in Epie/Atissa. This system still remains the most effective in community organisation, through sensitizing and mobilizing the entire citizenry.

In summary, it can be inferred that the Enwhe Development Project communities have a 5-level hierarchical and pyramidal governance structure. At the top of the pyramidal hierarchy is the Paramount Ruler followed by the Elders' /Chief's Council. The three last levels of the hierarchy are the Community Development Committee; the youths and women groups and other community-based organisations; and the individual members of the community at the bottom of the pyramid. This governance structure is furnished in Fig. 4.7a.

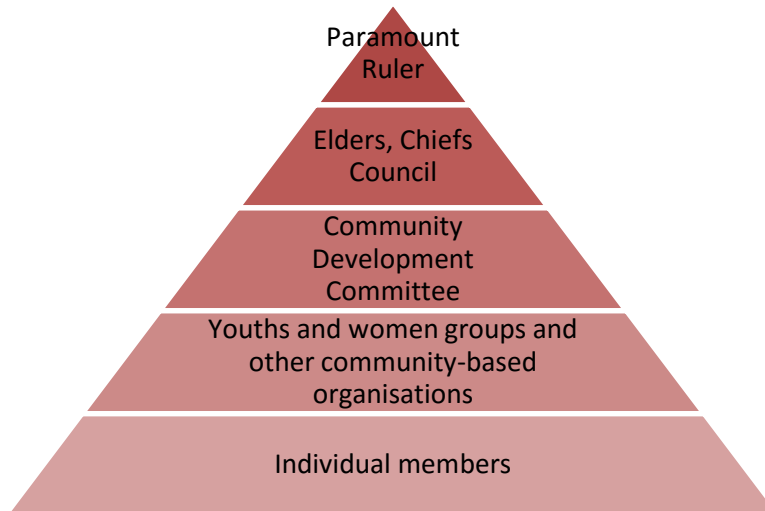


Fig. 4.7a: Five-Level Hierarchical/Pyramidal Governance Structure

4.7.12.4: Land Ownership and Use

Land is one of a plethora of natural resources very useful in production all over the world. Access to land either for use only and/or for ownership and use can be had through a number of ways in various communities/societies. They include outright purchase, inheritance, lease, mortgage, etc and, in the case of agriculture, share cropping. In the study area, access to land is usually by inheritance. Individual ownership of land is not very common as the local land market is still at its development stage. In this case, families and groups of families have custody of land in trust for individual members.

For example, in Emughan Clan which comprises Owerewere, Aminigboko, Emesu and Egunughan, land is owned by families. However, families who own land can out of benevolence or goodwill donate part to the community or government for public use in return for token compensation. In Gbaran and Igbuduya Clans also, land ownership is mainly by families and groups of families. Only male children inherit land but where there is no male child in a family, a male child of a female member could be entitled to land inheritance from the maternal family. However, when land is to be acquired for development purpose say by the SPDC or any other corporate organisation, the community serves as platform for all negotiations relating thereto. It is through the community leadership that such corporate organization that wants to acquire land goes through to the family or group of families that actually own the land to be acquired.

Land in the area is used mainly for farming and fishing purposes. Other indigenous uses of land are: hunting, lumbering, harvesting of non-timber forest products, as well as housing.



Plate 4.14a: Typical Agricultural landuse

4.7.12.5: Population and Socio-Demographic Information

The population of the 24 communities in the Enwhe FDP area, according to the 1991 census was 52,608 peoples. Out of this number, 27,871(53%) were males while the remaining 24,737(47%) were females. In terms of sex distribution, therefore, it can be argued that males were more than females in the area as at 1991. Using an annual population growth rate of 2.8%, the National Population Commission projected the population of the area for 1996, 2002 and 2006 at 72,260; 73,694; and 75,492 peoples, respectively. As part of this study, the population of the area was projected for 2015 and 2030 using an annual growth rate of 3.4% and the exponential growth model. The projected population for 2015 and 2030 are 98,593 and 128,763 peoples, respectively. The details of the population of the individual communities in the Enwhe FDP area are furnished in Table 4.14c.

The analytical models by (Palmore and Gardner,1983) adopted in arriving at the projected population, using the National Population Commission’s 2006 census figures as base year, are presented as follows:

- i) Linear Extrapolation Model

Where:

$$P_n = P_0 + P_0na \dots\dots\dots (1)$$

P_0 = the base year population,
 a = some fixed percentage of the base population (growth rate), and
 n = time elapsed in years.

ii) Exponential Growth Model

Where:

$$P_n = P_0 (1 + r)^n \dots\dots\dots (2)$$

P_0 = base year population;
 r = annual population growth rate, and
 n = time period in years.

The sociological definition of a household is the total number of persons living under one roof and eating food from the same pot. The most recent NDHS report (1999) found that small differences exist in the composition of urban and rural households by number of members; mean household size in rural areas is 5.1 compared to that of urban households which is 4.8. In Bayelsa State, for example, the typical rural (farm) households have been reported to be generally large, ranging between 2 and 25 people (Allison-Oguru, Zoufa and Berepubo, 1999). Similar study by the SPDC (2009) in the Gbaran Ubie Phase 2 IOGP (EIA Cluster 1) indicates average household size of 8. This is due mainly to the polygamous nature of marriages in the area and the high reproductive rate of women. However, some outlier households, which are very few in number (3.8%), have sizes of up to 17 persons. It can therefore be argued that households in the area have sizes exceeding the average household size of 5-6 reported for most of the Niger Delta region (Euroconsult, 1996; NDES, 1997).

The age distribution of the population of communities in the project area exhibits the typical pyramidal structure found for Nigeria as a whole. That is, the bulk of the population is made up of children and other persons below 26 years of age. For example, in a similar study in the Gbaran area by the SPDC (2009, *op cit*), almost a quarter of the sampled population are infants (0 – 4 yrs) and children of primary school age (5 – 12 yrs). These results suggest a young and growing population in the project area. With respect to sex distribution, the 1991 population census suggests that the number of males (53%) exceeds that of females (47%).

Dependency ratio (DR) is a measure of the burden on the working age population in having to cater for the welfare needs (food, clothing, medication, education, etc) of children and the aged in the population. The higher the non-working age population, the higher this ratio, and vice versa. Mathematically, the dependency ratio is given by the formula:

$$\frac{\text{Number of persons under 25 or over 60}}{\text{Numbers of person between 26 60 years old}} \times \frac{100}{1}$$

The national average dependency ratio, according to a (NISER, 2001), was about 87.4% over the 1996 – 1999 period. In the project communities, employment is still largely dependent on farming, fishing and other primary economic activities with meagre incomes. This fact coupled

with polygamy and high reproductive rates of women in the area, the degradation of land and water resources, and a generally high formal unemployment rate makes the dependency ratio to be palpably high. It is not surprising that the project area had witnessed lock-outs of SPDC facilities by youths demanding for employment opportunities for indigenes of oil/gas communities. It is visible that high dependency ratio exists in the project area and it is expected that the Enwhe FDP would address it.

Table 4.14c: Population Size and Growth of the Enwhe FDP Communities

Locality	Males	Females	Both_Sexes	1996_Proj	2002_Proj	2006_Proj	2015_Proj	2030_Proj	LGA	STATE
EMESU EMUGHAN ABUA	440	389	829	981	1,161	1,190	1,554	2,029	ABUA/O DUAL	RIVERS
OWEREWEBE EMUGHAN ABUA	4,884	3,820	8,704	10,301	12,192	12,490	16,312	21,304	ABUA/O DUAL	RIVERS
EGUNUGHAN EMUGHAN ABUA	796	696	1,492	1,766	2,090	2,141	2,796	3,652	ABUA/O DUAL	RIVERS
AMINIGBOKO EMUGHAN ABUA	3,051	2,738	5,789	6,851	8,109	8,307	10,849	14,169	ABUA/O DUAL	RIVERS
OKOBOH TOWN ABUA	2,280	2,022	4,302	5,091	6,026	6,173	8,062	10,530	ABUA/O DUAL	RIVERS
OBARANY EMUGHAN ABUA	1,282	1,160	2,442	2,890	3,421	3,504	4,577	5,977	ABUA/O DUAL	RIVERS
EMABU	0	0	0	0	0					
KARKI ENGENNI	2,707	2,625	5,332	8,310	7,469	7,651	9,993	13,051	AHOAD A	RIVERS
OPUOGIZOGOLO ENGENNI	114	106	220	260	308	316	412	538	ABUA/O DUAL	RIVERS
KALAOGBOGOLO ENGENNI	187	142	329	389	461	472	617	805	ABUA/O DUAL	RIVERS
KIOGBOLOGBO ENGENNI	339	339	678	802	950	973	1,271	1,659	AHOAD A	RIVERS
UNUSHA ENGENNI	343	350	693	820	970.69645 5	994	1,299	1,696		
KODI ENGENNI	1331	1363	2694	3188	3773.5299 42	3,866	5,049	6,594		
OGBOGOLO	0	0	0	0	0					
UGBOLOBOLO EKPEYE	866	748	1614	1910	2260.7562 46	2,316	3,025	3,950		

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Locality	Males	Females	Both_Sexes	1996_Proj	2002_Proj	2006_Proj	2015_Proj	2030_Proj	LGA	STATE
OGBEDE EKPEYE	886	703	1589	9881	2225.738336	2,280	2,978	3,889		
ODIEKE EKPEYE	354	359	713	844	998.7107827	1,023	1,336	1,745		
DIGWE EKPEYE	156	152	308	365	431.4206467	442	577	754		
OBOHDI	0	0	0	0	0		0	0		
OKUTUKUTU	968	702	1,670	1,976	2,340	2,396	3,130	4,087	NORTHERN IJAW	BAYELSA
OKOLOBIRI	3,103	2,955	6,058	7,169	8,488	8,693	11,353	14,827	NORTHERN IJAW	BAYELSA
OBINAGHA	1,381	1,297	2,678	3,169	3,752	3,843	5,019	6,555	NORTHERN IJAW	BAYELSA
AGUDAMA	1,593	1,409	3,002	3,553	4,206	4,308	5,626	7,348	NORTHERN IJAW	BAYELSA
AKENPA	810	662	1,472	1,742	2,062	2,112	2,759	3,603	NORTHERN IJAW	BAYELSA
TOTAL	27,871	24,737	52,608	72,260	73,694	75,492	98,593	128,763		

Source: NPC 1991/1996, Field Survey, 2016.

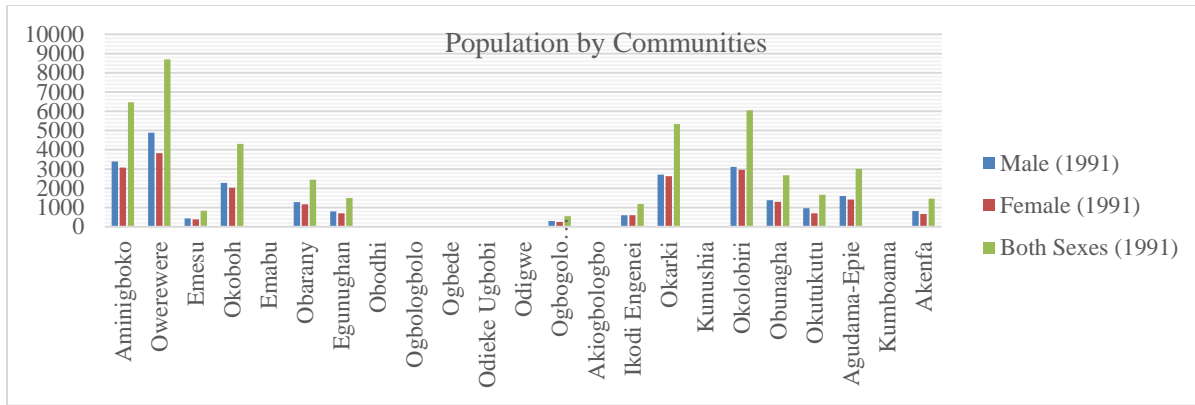


Fig. 4.7a: Projected Population of Enwhe Communities

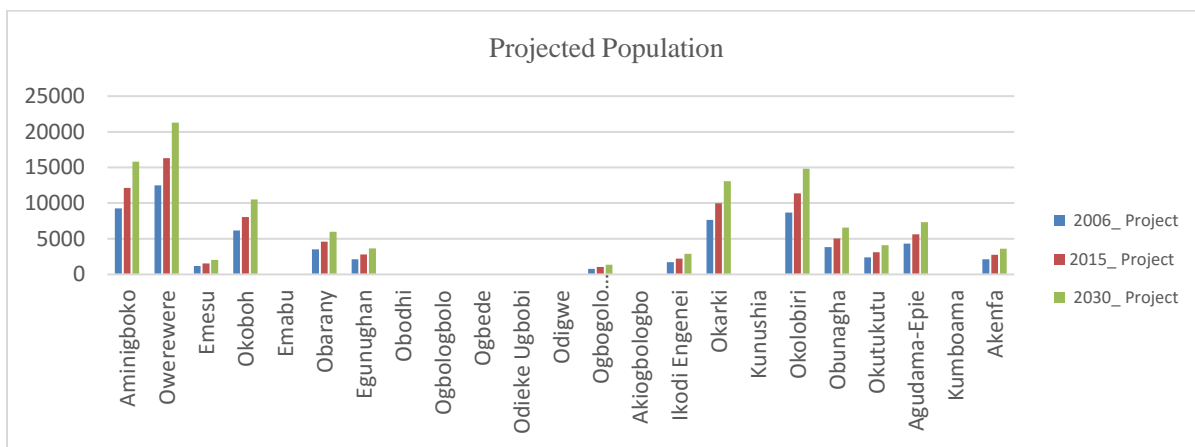


Fig.4.7b: Projected Population of Enwhe Communities

4.7.12.6: Livelihood and Micro-economy

Subsistence farming, artisanal fishing, lumbering and harvesting of non-timber forest products are the major traditional economic activities in the Enwhe FDP area. The farm implements and fishing gear used include diggers, cutlass and hoe, while fishing traps, canoe, hooks, nets, etc. Staples crops cultivated in the area include: cassava, plantain/banana, water yam, potato, okra, pepper, groundnut, cocoyam, etc. The surrounding forests, rivers, swamps, creeks and rivulets are viewed by communities in the area as sources of economic livelihood, as well as means of transport and commerce. Palm wine tapping and local gin production is another very common means of livelihood in the area though it is gradually becoming less indulged in by the natives.

Other sources of livelihood in the project area are motor cycle/try-cycle transportation, barbing/hair dressing salon, telephony, trading in foodstuff, provisions and drinks, masonry and building, as well as government employment. Apart from marketing what is derived from the forest and sea, cooked food, beverages (alcohol), palm oil, processed cassava, timber, and basic household items are daily on sale in the communities and surrounding markets the study area.

As is typical with most households in Nigeria in general and the Niger Delta in particular, personal and household incomes are difficult to assess for various reasons. Some of these reasons include: fear of divulging information on one's income for income tax reasons; and lack of records keeping habit to regularly and accurately income stream(s). In the case of communities in the Enwhe FDP area, it was not even feasible to undertake an interview of a cross-section of the households to be able to gather this information. However, in a similar study by the SPDC (*Op Cit*) it was reported that monthly household incomes range between N1,000 and N75,000. According to the said Report: out of the 132 households sampled, 7.5% earned less than ₦5,000 and between ₦ 25,000 – ₦30,000; (30.3%) earned between ₦5,000 – ₦10,000 while 15.1%, 12.1% and about 11% earned monthly incomes within the bracket of ₦10,000 – ₦15,000, ₦15,000 – ₦20,000, and ₦20,000 – ₦25,000, respectively. Furthermore, 13.6% of the households sampled reportedly earned monthly income between ₦30,000 – ₦45,000.00 while the remaining 3.0% earned above ₦45,000.00 per month as income. Generally, the income level of the project area is low. This could be due to the meagre income arising from their sources of livelihood and lack of others sources of additional income to supplement their main income.

The household expenditure patterns of the communities in the project area was generally observed to conform to the national trend in that food is the largest single expenditure item accounting for over 50% of monthly income and in some cases almost 100%. This observation suggests that households in the project area are generally income-poor. According to Fredrick Engel, the lower the level of income a household earns, the higher the percentage of it that is expended on food, and vice versa. Other items that households in the area expend their income on are: education of children; housing; health-care; social and cultural obligations; clothing; entertainment; travels; etc.



Plate 4.14a: Product of numerous water bodies and common fishing gear in the study area



Plate 4.14b: Forest Resources (Malaria/Typhoid herb, Mushroom, Palm fruit)



Plate 4.14c: Typical Plantain Plantation in the Enwhe field.



Plate 4.14d: Commercial palm oil extraction activities in Enwhe Field



Plate 4.14e: Lumbering activities in Enwhe field

4.7.12.7: Infrastructure facilities and Quality of Life

Communities in the study area were observed to have one or more infrastructural facilities such as rural electricity supply, primary and secondary schools, motorable road, health care, town hall, market, jetty, and pipe borne water. However, not all the infrastructural facilities in the communities surveyed are in functional state.



Plate 4.14f: Typical mud houses in the communities



Plate 4.14g: Typical Block wall houses in the communities

Electricity Supply and Household Energy

The communities in the study area have access to electricity supply; they are all linked to the national grid. However, the incessant power outages nationwide and in the project area have robbed the communities of the joy of the facility. Obunagha, one of the FDP communities is the only one that gets power from the existing Gbaran facility, with other neighboring communities clamoring for the same treatment.



Plate 4.14h: Light Energy Transmitting Facilities

Water Supply and Sanitation Facilities

Generally, the rural communities in Nigeria and the Niger Delta have less access to potable water supplies than their counterparts in the urban area. The riverine areas are particularly worse off in this regard as less than 24% of them have access to safe drinking water (Euroconsult, 1996; Fieldwork, 2000; Fieldwork, 2016). In spite of the fact that water abound in the area, there is scarcity of potable water in the communities. As a result, most communities in the project area depend on the nearby river, creek, pond or local well for their daily water needs. Others rely on rain harvesting with its health hazard as source of domestic water supply.

Apart from Obunagha and Odieke Ugbobi which have pipe borne water facilities provided by the SPDC and one Monday Egbuluka (a private borehole owner), the primary sources of domestic water for the remaining communities include water vendors, nearby creek/river and rainwater. Water project initiated by SPDC in Ogbologblo and Odieke Ugbobi are not functioning; the solar propelled Agip water in Obodhi is also non-functional. See below pictures of moribund water

projects and open dumping and incineration of domestic waste in some communities in the FDP area.



Plate 4.14i: Water supply from Hand-dug well in one of the communities



Plate 4.14 jPrivate borehole water supply in one of the communities

Transport and Communication (Road Infrastructure Inclusive)

The transportation network of communities in the Enwhe FDP is diverse. While some areas are easily accessible motorable road, Obodhi community can only be accessed through bush track or farm roads. Emesu cannot be easily accessed during the rainy season due to the marshy and slippery landscape. The other communities are still benefiting from the tarred roads and access routes constructed by the SPDC for its exploration activities. However, within the communities, earth roads are common features of the streets. These roads are not accessible to motorists as they are usually muddy or even flooded at the peak of the rainy season.

There are no postal services in the project area but there are telecommunication masts of the Global System of Mobile Communication (GSM) providers such as MTN, Etisalat and Airtel whose signal strength fluctuates. Banking facilities are non-existent in the area.

Markets/Market Stalls

An open market stall facility built in Okarki by the Rivers State Fadama Programme was observed during the ground trotting exercise, while most of the houses along the road in the slight urbanized settlements were observed to serve as both residential and retail market outlets/shops. It is important to mention that all the communities were observed have their own local markets and market days.



Plate 4.14I: Open Market Stall in one of the Communities



Plate 4.14j: A Food Vendor in an open market in one of the communities



Plate 4.14k: Okarki Jetty



Plate 4.14l: Common mode of transport (Motorcycle)



Plate 4.14m: Common mode of transport (watercrafts)

Table 4.14d: Total Summary of Infrastructure Available in Host Communities

SN	Clan	Community	Electricity	Primary School	Road	Secondary School	Health Care Facilities	Townhall	Market	Jetty	Water system	
1	Emughan	Aminigboko		AF	AF		ANF				AF	AF
2		Owerewere		UC		UC	AF					
3		Emesu		AF			AF					
4		Okoboh		AF								
5		Emabu		AF								
6		Obarany		AF								
7		Egunughan		ANF								
8	Igbuduya	Obodhi		ABI							ANF	
9		Ogbologbolo		AF		AF	ABI				ANF	ANF
10		Ogbede		AF			AF					
11		Odieke Ugbobi		AF							ANF	
12		Odigwe										
13	Engenni	Ogbogolo (Ogbogolo, Ogbogolo, Ogbogolo, Egboama Ogbogolo) Opu Kala		AF								

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SN	Clan	Community	Electricity	Primary School	Road	Secondary School	Health Care Facilities	Townhall	Market	Jetty	Water system
14		Akiogbologbo		AF			AF				
15		Ikodi Engenei		AF		AF	AF				
16		Okarki		AF		AF	AF	AF	AF	AF	
17		Kunushia		AF							
18	Gbaran	Okolobiri		AF							
19		Obunagha	AF	AF	AF		AF				AF
20	Epie	Okutukutu									
21		Agudama-Epie									
22		Kumboama		AF (2)							
23		Akenfa									

Legends: AF- Available, functional; NA- Not available; ANF- Available, not functioning; ABI- Available but ill-functioned; UC- Undergoing construction

	SPDC		Government/ Community		Other IoC		Not sure		Others/ Private
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4.7.12.8: Housing and House types

According to the World Health Organisation (WHO), housing is a basic social need and an integral part of the human environment and the physical structure of settlements. WHO cited in Owei, O et al, 2002 has defined housing as “residential environment which includes in addition to the physical structure that man uses for shelter, all necessary services, facilities, equipment and devices needed or desired for the physical and mental health and social well-being of the family and individuals. Housing in the Enwhe FDP communities is a mixture of modern and traditional designs and construction materials. With the exception of communities in the Igbuduya Clan, houses in the other communities were observed to be clustered. In the case of Communities in the Igbuduya Clan the houses are separated by bush and patches of farm land. Houses are found along the main transportation and communication routes traversing the communities with these becoming much more compact and nucleated at the junctions of the roads and commercial or trade zones.

A few of the houses have modern designs and are built with improved utilities like kitchen, toilet and bath. Most houses in the communities are also constructed with stable and permanent materials like cement blocks and roofed with corrugated iron sheets. However, in the Igbuduya, Ogbogolo and Abua/Odual areas, a good number of the houses have roofs made up of corrugated iron sheets with mud or wooden walls.

In the Gbaran and Epie/Atissa areas, most houses across the communities are bungalows and flats. The bungalows are built with many rooms and are mostly multi tenanted. A few houses are built with single rooms or as self-contained units of room and parlour for commercial purposes. Bungalows account for more than 50% of houses in these communities. At Ogbologbolo community, housing stock comprised 35% block-wall, 50% mud-wall while 15% are thatched. The Odieke Ugbobi community has over 300 housing structures sparsely spaced out and separated by bushes mixed with economic trees. Housing stock comprised mainly of block wall. 20 buildings are zinc (batcher), while few houses are thatched (about 10) most especially kitchen huts; while at Owerewere over 350 housing structures in a more compact form can be found lining the roads and streets.

Housing characteristics are also very distinct in the communities of Obodhi and Aminigboko where housing stock is made up of 25% block wall, 40% thatch and 35% mud/zinc wall in Obodhi, while majority of houses in Aminigboko are bungalows with about 20% stock being of mud or thatched structure. Housing characteristics in Obunaghan community are predominantly of the brick-walled types, with corrugated iron zinc roofing, although storey buildings are rare. (see plate 4.14 f & g)

4.7.12.9: Perceptions, Need, Interest, Concerns and Expectations from Proposed Projects

Social Problems in the Communities

During the consultation meetings and socio-economic survey several concerns and expectations were expressed. Respondents at the consultation forum were not pleased with SPDC activities in the areas of employment of indigenes and the provision of basic infrastructure. They are particularly bitter that repeated studies have been carried out and their expectations (demands) articulated, yet nothing seems to have been done by the SPDC. They therefore did not mince words in remarking that SPDC should show human face and be more proactive in these areas with the inception of the Enwhe FDP.

Table 4.14e: Summary of Benefits, Impacts and Expectations of the communities

SN	CLAN	COMMUNITIES	INTEREST AND EXPECTATIONS
1	Emughan	Aminigboko	<ul style="list-style-type: none"> ▪ Rehabilitate community road ▪ Civic center ▪ Employment opportunities for its people ▪ Provision of tarred roads ▪ Scholarship for its teeming youth population ▪ Contracts should be awarded to community members ▪ Scholarship entrance waver for Emughan sub-clan children and slots must be filled by their children using list provided by Paramount ruler of the communities ▪ Health clinics should come back to life with SPDC cooperating with local government
2		Owerewere	
3		Emesu	
4		Okoboh	
5		Emabu	
6		Obarany	
7		Egunughan	
8	Igbuduya	Obodhi	<p>Odigwe:</p> <ul style="list-style-type: none"> ▪ Inter-community road network ▪ Provision of tarred roads with drainages. ▪ Provide security post and deployment of police for protection of life and properties. ▪ Hold workshops to enlighten community members on evils of cultism <p>Ogbede:</p> <ul style="list-style-type: none"> ▪ Road construction and provision of drainages ▪ Youth empowerment ▪ Employment of indigenes ▪ Provision of portable water ▪ Security and surveillance of pipelines or facilities should be restricted to families whose property is impacted. ▪ Completion of health center and primary school in their community ▪ Have an MOU with community beside the collective one
9		Ogbologbolo	
10		Ogbede	
11		Odieke Ugbobi	
12		Odigwe	

SN	CLAN	COMMUNITIES	INTEREST AND EXPECTATIONS
13	Engenni	Ogbogolo (Ogbogolo, Opu Ogbogolo, Kala Ogbogolo, Egboama Ogbogolo)	<ul style="list-style-type: none"> ▪ Road network and drainages ▪ Portable drinking water ▪ Health center ▪ Electricity ▪ Grant scholarship to their children
14		Akiogbologbo	<ul style="list-style-type: none"> ▪ Youth empowerment ▪ Provide agricultural center ▪ Town Hall ▪ Craft Center ▪ Good road network and drainages ▪ Employment opportunities in SPDC ▪ Provide portable water
15		Ikodi Engenei	<ul style="list-style-type: none"> ▪ Build town hall ▪ Provide electricity to the community ▪ Build market stalls ▪ Provide portable water ▪ Grant employment and scholarship to their children
16		Okarki	<ul style="list-style-type: none"> ▪ Good road network ▪ Housing ▪ Establish a Police Post in the community ▪ Upgrade and equip secondary and health center
17		Kunushia	<ul style="list-style-type: none"> ▪ Provide good road network and drainage system ▪ Provide electricity, Hospital, Craft Center and Schools ▪ Provide portable water and community market stalls ▪ Grant scholarship and employment to youths
18	Gbaran	Okolobiri	<ul style="list-style-type: none"> ▪ Connect Gbaran clan to CPF or Etelebo Power Plant
19		Obunagha	

SN	CLAN	COMMUNITIES	INTEREST AND EXPECTATIONS
20	Epie	Okutukutu	<ul style="list-style-type: none"> ▪ Give each community portable water supply project that will stand the taste of time
21		Agudama-Epie	
22		Kumboama	
23		Akenfa	

The research reveals the following community concerns and suggestions to mitigate and enhance socio-economic impacts. Holistically, most communities clamour for permanent employment to the children of the area, commensurate compensation for acquired lands and good roads. Specific details are contained in the Table 4.14f.

Table 4.14f: Summary of Concerns and Priority Interest of the communities

SN	CLAN	COMMUNITIES	CONCERNS AND PRIORITY INTEREST OF COMMUNITIES
1	Ekpeye (Emughan)	Aminigboko	<ul style="list-style-type: none"> ▪ Reduction in fish catches as a result of oil pollution 3 months before this study from activities of Avengers. There was major spill 3 years ago. ▪ Leadership tussle in Aminigboko; power tussle between cultic groups- Islanders and Greenlander in Owerewere
2		Owerewere	
3		Emesu	
4		Okoboh	
5		Emabu	
6		Obarany	
7		Egunughan	
8	Igbuduya	Obodhi	<ul style="list-style-type: none"> ▪ Fear of increase in communicable diseases (STD). ▪ Heads of settlements corners benefits meant for the youths of their communities. ▪ Chiefs/Eze's are Patrons of cult groups in Ekpeye kingdom ▪ Perennial flooding of community ▪ Security issues
9		Ogbologbolo	
10		Ogbede	
11		Odieke Ugbobi	
12		Odigwe	
13	Engenni	Ogbogolo (Ogbogolo, Opu Ogbogolo, Kala Ogbogolo, Egboama Ogbogolo)	<ul style="list-style-type: none"> ▪ Divide and rule may cause unprecedented problem ▪ Project may turn women and girls wild ▪ Fear of increase in communicable diseases ▪ Marine pollution over time ▪ Increase in divorce cases as a result of infidelity ▪ Fear of facility explosion ▪ Security concerns ▪ Air pollution during construction and decommission phase ▪ Increase in social vices
14		Akiogbologbo	
15		Ikodi Engenei	
16		Okarki	
17		Kunushia	
18	Gbaran	Okolobiri	<ul style="list-style-type: none"> ▪ Oil activities in Gbaran have brought in cultism, criminality and distrust.
19		Obunagha	

SN	CLAN	COMMUNITIES	CONCERNS AND PRIORITY INTEREST OF COMMUNITIES
20	Epie	Okutukutu	<ul style="list-style-type: none"> ▪ Health centers are moribund ▪ Increase in population ▪ Hike in prices of commodity ▪ Security concern and kidnap on the rise ▪ Increase in number of women of easy virtues (prostitution) ▪ Increase in sexually transmitted diseases such as gonorrhoea ▪ Progressive decline in revenue derived from fishing and games hunting ▪ Destruction of medicinal plants and herbs along the land acquired for oil facilities and prospecting ▪ Insensitive to plight of communities ▪ March amiable complaints or protest with JTF harassment, intimidation and oppression ▪ Disruption of economic activities whenever work starts on acquired sites with ban or restriction for community from the area not minding if it is an access to their economic activity area with compensating inconveniences. ▪ Stop unnecessary harassment of communities using JFT whenever they voice displeasure of SPPDC treatment or activities in a community. ▪ Lack of portable water supply ▪ Lack of electricity ▪ SPDC should pay for inconveniences caused as a result of restriction on the activity area(s) of economic pursuit of community members wherever applicable ▪ Revegetate ROW with same native plant/herb species
21		Agudama-Epie	
22		Kumboama	
23		Akenfa	

4.8.13: Health Profile

Secondary data on health status of the communities within the study area was obtained from previous studies on Obunagha community around the Gbaran Central Processing Facility. Patent medicine stores are most times the first point of call for sick individuals within the community. The health conditions of the communities around the project location are similar to those of the communities within the Niger delta region, especially the Orashi region of Rivers State.

4.8.13.1 Morbidity pattern

Focus Group Discussion (FGD) sessions were held with community representatives to ascertain the health condition of members of the communities within and around the Enwhe field. Common causes of ill health were said to be malaria, typhoid fever, upper respiratory tract infections, skin diseases and diarrheal diseases. These health problems reported by discussants at the FGD sessions held in the communities were comparable to records of public health facilities that serve the various communities; and consistent with diseases seen in other communities in Niger Delta (NDHS, 2008). Road traffic accidents occur in the communities, especially as motorcycles are still a major means of commercial transportation. The results of the traffic analysis carried out in the communities during the field study showed an average of 20 motor vehicles (including motorcycles) every 30 minutes, along the major roads that transverse the communities. Traffic was significantly more in the Gbaran communities within Bayelsa State.

4.8.13.2 Prevalence of Non-communicable diseases

Similar to situations in several rural communities in the Niger delta, the incidence of non-communicable diseases like hypertension and diabetes mellitus are beginning to rise. An indication of this was obtained during the focus group discussions conducted in the communities, and corroborated by the results of the random measurement of blood pressure carried out during the field study. Discussants at the focus group discussion sessions could not identify anyone that died of cancer in their respective communities, even though they believed oil exploration and exploitation activities could cause cancer.

4.8.13.3 Mortality pattern

Under-five and maternal mortality rates are falling within the communities. This was acknowledged during the focus group discussions held in the communities. The mortality rates in the communities were comparable to those of neighboring communities. Reports of maternal mortality was said to be as low as once a year within the communities. This decrease in maternal mortality was attributed to the training of traditional birth attendants in the communities, and the swiftness with which emergencies were recognized and referred to health centers, for appropriate treatment. Causes of maternal deaths recorded in the communities within the last five years, according to discussants included prolonged labour, post-partum hemorrhage, abortion and eclampsia. These causes are also consistent with the findings in other communities in Nigeria (NDHS, 2008).

Common causes of under-five mortality include: malaria and its complications, especially anemia and febrile convulsion; gastro-enteritis (diarrhoea and vomiting), acute lower respiratory tract infection; and vaccine preventable diseases like measles. These causes are also common in most communities in south-south Nigeria (NDHS, 2008), and they point to poor environmental conditions, poor health seeking behaviour, and poor standard of health care delivery in the communities.

4.8.13.4: Health Care systems

Primary Health Centers

Most of the communities, have a primary health facility located within the prescribed 5km distance, or 30-60 minutes travel time. The Primary Health Care facilities are either sited in the communities, or have the communities as part of their catchment area.



Plate 4.15a: Aminigboko cottage hospital

Table 4.15a: List of primary Health care facilities in the host communities

S/N	COMMUNITIES	PRIMARY HEALTH CENTRE	STATUS
1	Aminigboko Owerewere	Cottage Hospital Aminiwere	Has a cottage hospital built by SPDC between Aminigboko and Owerewere communities, but managed by the Rivers State government. Was said to be non-functional, due to the security situation in the community
2	Emesu	Emesu Health Center	
3	Egunughan	None	The Egunughan community is one of the catchment communities of Aminiwere Cottage Hospital
4	Okoboh, Emabu, Obarany	None	Catchment communities of Emesu and Aminigboko health centers
5	Okarki	Primary health center Okarki	Received serious facility and manpower upgrade during the Gov. Amaechi administration.
6	Ikodi	Primary health center Ikodi	Received serious facility and manpower upgrade during the Gov. Amaechi administration.
7	Kunushia	None	One of the catchment communities of Ikodi health center
8	Akiogbologbo	Agiogbologbo health post	Currently housed in the school compound. Has a few Community Health Workers that provide mainly immunization services
9	Ogbogolo, Ogbogolo, Ogbogolo, Opu- Kala-	None	Catchment communities of Aminigboko Cottage Hospital
10	Ogbologbolo	Primary health center Ogbologbolo	Barely functional. Poorly staffed, poorly equipped.
11.	Odieke	Primary health center Odieke	Barely functional.
12	Obodhi	Primary health center Obodhi	Barely functional.

S/N	COMMUNITIES	PRIMARY HEALTH CENTRE	STATUS
13.	Ogbede	Primary health center Ogbede	Built by the Local Government and barely functional. Offers mainly immunization services with few health workers
14	Kumboama	Niger Delta Teaching Hospital Okolobiri	Catchment community of the teaching hospital at Okolobiri
15	Okolobiri	Niger Delta Teaching Hospital Okolobiri	Catchment community of the teaching hospital at Okolobiri
16	Obunagha	Obunagha health center	Functional. The health center currently operates in a temporary site, as finishing touches are being made to a permanent facility.



Plate 4.15b: Public Health Center at Obunagha is being constructed

Most of the health centers in the communities are however poorly equipped, and do not offer regular medical services. Pharmacies of health centers lack essential drugs, mainly because they do not have a proper drug revolving scheme. Many members of the communities were therefore forced to engage in self-medication with drugs acquired from questionable sources. In some cases, health facilities were not open because health workers were on strike. Shortage of manpower, insecurity and truancy amongst the health workers also affect the effectiveness of health centers within the study area.

4.8.13.5: Secondary Health care facilities

The members of the Emughan clan access secondary health care services from the Aminigboko cottage hospital, built by SPDC but currently being managed by the Rivers State government. The hospital is well equipped, but is currently non-functional, due to insecurity within the community.

4.8.13.6: Tertiary health care

Tertiary health care centers such as Niger Delta University Teaching Hospital, Okolobiri; Federal Medical Center, Yenagoa; and the University of Port Harcourt Teaching Hospital, Port Harcourt; are accessible to communities in Rivers and Bayelsa State. These tertiary health care facilities have more than two thousand in-patient beds between them, and provide services in almost all specialties of medicine including emergency care, orthopedics, medical and surgical care, and at a cost that is affordable to a large proportion of the population.



Plate 4.15c: The Niger Delta University Teaching Hospital Okolobiri

4.8.13.7 Household Food Security and the nutritional status of under-five children

Members of the communities regularly eat local staples such as cassava, yam, cocoyam and plantain. These starchy foods are usually complemented with fish, which is another major agricultural produce of these communities. Household food security in the communities was said to be good, but worsening in recent years, due to flooding and insecurity. The discussants at the FGDs however believe the situation would get better with the incoming Field Development Project, as they expect to get employment and contracts for the supply of various items during the construction phase of the project.

4.8.13.8: Use of alcohol and tobacco

Similar to communities in the South-South region of Nigeria, alcohol and tobacco are commonly used. According to discussants, smoking was said to be common amongst young men; women rarely smoked. Alcoholic beverages, including the locally distilled gin called *kai-kai* or *ogogoro*, were said to be readily available at all times. Alcoholic beverages are commonly used during social functions (e.g. burial, weddings) and in ancestral worship. In addition, alcohol is commonly used as solvent for several traditional medicine, ranging from pain relief to aphrodisiac.

4.8.13.9: Sexual behavior

The sexual behavior of members of the communities can encourage the transmission of sexually transmitted infections, including HIV/AIDS. Polygamy is common, with most adult males having multiple sexual partners. Marital infidelity is also common and culturally tolerated for men. More detailed information about the sexual behavior of members of the communities could not be gathered during the field study due to community restiveness; but discussants at the focus group discussions held with representatives of the communities were unanimous on the fact that their sexual behaviors were no different from other communities around.

4.8.13.10: Knowledge of HIV/AIDS

All the discussants in the focus group discussion conducted have heard of HIV/AIDS; and some of them knew someone suspected to have the disease. More than two-third of the discussants were able to mention at least two routes of transmission of HIV/AIDS. The influx of people, especially the working class population is associated with an increase in the prevalence of HIV/AIDS and other STIs in the host community (*Nwauche and Akani 2006*), thus the need for sexual health education within the communities, considering the likely influx into the communities during the proposed project.

4.8.13.11: Medical Emergency Evacuation System:

There are no formal medical emergency evacuation systems in any of the host communities. Members of the communities make their own private arrangement in conveying their sick to health care centers for appropriate treatment.

4.8.13.12: Access to safe drinking water

Main sources of drinking water in the communities include sachet/bottled water, river, borehole and rain. Most water borehole facilities were provided by government and oil companies that operate in the area. These facilities were however non-functional during the duration of the field study.

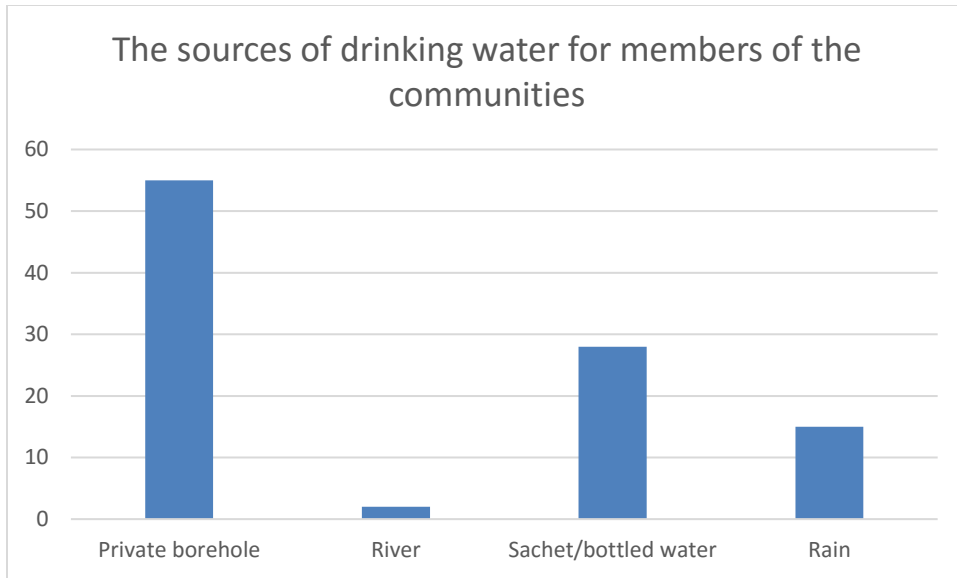


Fig. 4.8a: The sources of drinking water of members of the communities



Plate 4.15d: Water facility in the Emughan communities



Plate 4.15e: The Obunagha reticulated water facility (Non-functional)

4.8.13.14: Access to sanitation facility

Most members of the communities do not have sanitation facility within the recommended 50m of their houses (NDHS, 2008). Majority of the communities participated in open defecation and the use of jetty-type toilet. Few households had access to proper sanitation facility; and these households were mainly resident of modern houses within the communities.



Plate 4.15f: The toilet facility directly piped into the river in Obunagha community

4.8.13.15: Housing

Several houses in the communities were built with mud walls but there is an increasing trend in modern house construction with bricks especially in Gbaran communities close to Yenagoa main town. Some of the houses in the communities were raised from the ground, as safeguard against

the seasonal flooding that often plagues the communities. Rooms of various houses were poorly ventilated, and offered little protection against disease vectors and pests, especially as the communities are in close proximity to rivers, ponds and forest.

4.8.13.16: Vector/pest control

The following disease vectors were identified during the field study:

- Anopheles mosquito – the vector for malaria
- Culex mosquito – the vector for filariasis
- Aedes aegypti mosquitoes – the vector for yellow fever
- Tsetse fly (*Glossina* sp.) – the vector for sleeping sickness
- Sand flies (*Phlebotomus* spp.) – the vector for Leishmaniasis
- Housefly – carrier of enteric infections such as dysentery, typhoid and diarrhea; and eye infections such as trachoma and epidemic conjunctivitis

Of all these vectors, the nuisance and diseases caused by mosquitoes are most seriously felt in the communities. The prevalence of diseases transmitted by vectors (apart from mosquito) were stated to be generally low.

4.8.13.17: Indoor and outdoor Air quality:

Firewood is the commonest source of fuel for domestic use in the study communities. It is also the main fuel used in fish drying, the predominant method of fish preservation in the communities. The use of firewood and other bio-mass fuel as domestic fuel is a major cause of indoor air pollution, with wide-ranging health implications.

4.8.13.18: Waste management

The wastes generated in the communities were mainly domestic waste and agricultural waste. These wastes are often dumped close to residential accommodation, such that the complaints of houseflies, sandflies, rats and other vectors and pests that breed in such wastes are common in the communities; in spite of their best efforts at environmental sanitation. Leachates from waste dump sites can be a major source of contamination to streams and other water bodies in the communities.

4.8.13.19: Socio-economic characteristics

Most communities within the study area are semi-urban and are located within the freshwater swamp forest ecological zone of the Niger delta region. Farming is a major occupation within the communities of interest. Farming activities usually start at the beginning of the dry season, when the seasonal flood begins to recede. Agricultural produce common in these communities include cassava, yam, cocoyam, sweet potato, plantain, banana and vegetables. Fishing is also a major occupation, and is carried out in the Orashi river and other water bodies in the communities. Some communities also have reserved water bodies which are harvested after some years of being left

untouched. Trading, production of palm wine, local gin and palm oil are also common within the communities. The production of wine and local gin are derived from the raffia palm that grow in the freshwater swamp forests that surround communities. Palm oil is produced from the palm oil tree that grows in drier parts of the communities.

CHAPTER FIVE

POTENTIAL AND ASSOCIATED ENVIRONMENTAL IMPACTS

5.1: Introduction

A number of methods exist for evaluating potential impacts of any project on the environment. These include the Overlays techniques (McHarg, 1968), Leopold matrix (Leopold *et al.*, 1971), Battelle Environmental Evaluation System (Dee *et al.*, 1973), and Peterson Matrix (Peterson *et al.*, 1974) and ISO 14001. The method employed in this EIA study is the ISO 14001 method. The ISO 14001 method is simple to apply and provides a high level of detail, and also relies on limited data. The following considerations were adopted in this impact assessment:

- Comprehensiveness - ability to handle all possible range of elements and combinations thereof;
- Selectivity - capability to identify early in the procedure those aspects that are important;
- Mutual exclusiveness - should be able to examine every component of an impact from different perspectives;
- Confidence limits - is the method able to ascertain and isolate uncertainties?
- Objectivity - should allow no bias either from the assessor or project initiator;
- Interactions - should be able to examine both sides of a coin and provide feedback.

5.2: Uncertainties

In our efforts to produce a credible EIA report, we are constantly assailed by the problem of uncertainties. Any Impact Assessment contains five kinds of uncertainties. These are uncertainties due to:

- The natural variability of the environment, particularly the occurrence of rare events such as floods, unpredictable climate change and natural disasters;
- Inadequate understanding of the behaviour of the environment;
- Inadequate time-tested data for the area being assessed;
- Socio-economic uncertainties (inadequate data for prediction of human response to economic crises). There is always uncertainty in predicting the way a community will respond to the activities of oil companies in their domain.
- Health uncertainties such as the problem of determining the direct causes and effects of diseases, and that of ascertaining the disease vectors that are brought into the project environment by itinerant applicants.

In this study, we have endeavored to use available cost-effective techniques and review of published data to mitigate these uncertainties where possible.

5.3: Impact screening

Comprehensive checklists of developmental activities and possible environmental/health/social impacts were produced, and based on past experience and reviews of literature and Impact Assessment reports on similar projects; these lists were tailored to specific project components and associated historical effects.

Basis for Screening

The rationale for assessing the likely impacts of the proposed project derives from the following considerations:

- Knowledge of the project activities, equipment types, material inputs/outputs and operational procedures;
- Provide an initial assessment of the likely key environmental considerations;
- Findings of other EIA studies on similar projects and other literature findings on the primary project activities;
- Comparison with Environmental Guidelines and Petroleum Industries in Nigeria, 2002;
- Series of expert group discussions.

The criteria applied to the screening of various activities are:

- Magnitude - probable level of severity.
- Prevalence - likely extent of the impact.
- Duration and frequency - likely duration - long-term, short-term or intermittent.
- Risks - probability of serious impacts.
- Importance - value attached to the undisturbed project environment.

In assessing potential impacts, cognizance was taken of the inherent judgmental subjectivity involved; consequently, the analytical results of field studies, relevant literature reviews and observations of existing facilities and practices were used to assess the level of potential impacts of the proposed project.

5.4: Determination of project activities

This involves the determination of individual project activities to be undertaken in the respective phases as described in Chapter 3. A list of activities which interact with the biophysical, social and health environments either due to their nature or due to timing is summarized in Table 5.1.

Table 5.1: Phases of project development activities used in Interaction Matrix

S/N	Project phase	Project activities
1	Pre-mobilization	Consultation, Land acquisition and Compensation
2	Mobilization	Movement of equipment and personnel, Rig movement
3	Construction	Route & location clearing (site preparation), Dredging & Sand filling, Pilling, Concrete and asphalt works, Excavation, Backfilling, Pipeline coating, Stringing & welding; NDT and cathodic protection, Base camp activities, Drilling and well hook-up, Well & pipeline testing, Cathodic Protection, Commissioning & Handover
4	Demobilization	
5	Operation	Well work-over, Gas production, Pipeline maintenance & replacement
6	Decommissioning and abandonment	Flushing of pipelines, Vacuum drying of pipeline, Capping of pipeline, Removal of surface installations, Plugging of wells, Site restoration, Return of land to owner(s)

5.5: Determination of sensitivities

The determination of sensitivities that characterize the biophysical and social environment was carried out by the environmental consultant teams (biophysical, social and health) using their knowledge of the integrated baseline data. Table 5.2 presents the list of environmental sensitivities.

Table 5.2: Sensitivities describing Biophysical, Social and Health Environments of Enwhe field

S/N	Environmental components	Environmental sensitivities
1	Biophysical Environment	Air quality, Level of noise and vibrations, Surface water quality, Groundwater quality, Soil and sediment quality, Access to farming and hunting grounds, biodiversity (vegetation and wildlife)
2	Socio-economic Environment	Access to ancestral and culturally significant sites, Safeguarding traditional occupations, Cost of living/Inflation, Opportunities for economic enhancement, Skill Acquisition, Boom and bust economy, Access to sanitation and waste management, Balance in gender, Lifestyle (use of alcohol, drugs, physical activities etc.), Morals and family values, Current levels of youth restiveness, Current level of workers safety, Current level of road traffic accidents
3	Health Environment	Access to and quality of clean drinking water, Exposure to nuisance (dust, noise etc.), Level of disease & disease

S/N	Environmental components	Environmental sensitivities
		vectors (including STDs), Access to primary health care, Access to traditional medicine

Interaction Matrix

Interactions between project activities and sensitivities were determined by a group of experts using their background knowledge of the project and its biophysical, social and health environment. Each interaction was discussed followed by an assessment as to whether the effect of the interaction was expected to be positive or negative. The identified impacts were further listed according to the phases of the project in which they are likely to occur in order to identify those impacts which cut across different phases of the project activities. The interaction matrix is presented in Table 5.3. In the interaction matrix, the following codes are used:

- (+) = likely positive effect of the project;
- (-) = likely negative effect/interaction of the project,
- (+/-) = when the interaction can both be positive and/or negative.

Table 5.3: Interaction Matrix

Project Phase	Project Activity	Description of Impact	Nature of Impact
Pre-mobilization	Consultation, Land acquisition and Compensation	Increase in project awareness	(-)
		Anticipated Loss of land associated resources	(-)
		Financial enhancement	(+/-)
		Third party agitation	(-)
Mobilization	Movement of equipment and personnel, Rig movement	Loss of livelihood	(-)
		Increase in road traffic, potential for accidents and injuries	(-)
		Employment for the project community members	(+)
		Damage to road infrastructure	(-)
		Influx of people causing Pressure on health and other Infrastructure	(-)
		Increase in sexually transmitted disease and other communicable diseases	(-)
		Reduction in air quality	(-)
		Loss of vegetation and wildlife	(-)
		Habitat fragmentation	(-)
		Loss of aquatic species (Fisheries, Planktons and benthic fauna)	(-)
		Distortion of aquatic environment (physical components)	(-)
		Increase in noise and vibration	(-)
		Increase in refined hydrocarbon contents of soil and vegetation	(-)
Loss of cultural/heritage sites	(-)		
Contamination of groundwater	(-)		
Soil compaction	(-)		
Increase in waste	(-)		
Construction	Wells/locations/pipelines Route & location clearing, Pipeline crossing, Excavation Backfilling	Increase in respiratory tract infection	(-)
		Increase in population due to influx of persons	(-)
		Increase in social vices (Alcohol and drug abuse, CSWs)	(-)
		Crime and insecurity (Kidnapping, Hostage-taking, armed robbery, Militancy)	(-)

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Project Phase	Project Activity	Description of Impact	Nature of Impact		
	Pipeline coating Stringing & welding; NDT and cathodic protection Base camp activities	Injury/fatality of workforce and/or third party	(-)		
		Road traffic disruption	(-)		
		Increase in volume of wastes	(-)		
		Increase in employment/business opportunities	(-)		
		Shift from traditional occupations	(-)		
		Inflation	(-)		
		Gender imbalance	(-)		
		Employment for the project affected community members	(+)		
		Potential for skills acquisition	(+)		
		Pressure on existing infrastructure and services (Water, Electricity, Recreational facilities, Health facilities, Roads and others)	(-)		
		Increase in communicable diseases, STIs HIV/AIDS	(-)		
		Change in topography	(-)		
		Change in hydrology (groundwater)	(-)		
		Surface water pollution/distortion	(-)		
		Soil pollution	(-)		
		Loss of biodiversity and Distortion of food chain	(-)		
		Impairment/Loss of aquatic life	(-)		
		Increase in disease vectors	(-)		
		Blockage of natural water courses	(-)		
		Increase in road traffic/ potential for accidents and injuries	(-)		
				Decrease in nutritional status	(-)
				Erosion	(-)
				Loss of indigenous languages	(-)
				Loss of fish breeding sites and migratory routes	(-)
				Noise and vibration	(-)
				Reduction in air quality	(-)
		Opportunity for direct and indirect Employment	(+)		
		Opportunity for wealth creation	(+)		
		Opportunity for Corporate Social Responsibility	(+)		

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Project Phase	Project Activity	Description of Impact	Nature of Impact
		Exposure to radioactive materials	(-)
		Third party agitation	(-)
		Potential attack from wild/predatory animals (Snakes, Scorpions)	(-)
		Increase in exposure to trans border diseases (Zika virus, Ebola, Birdflu, SARS), Antimicrobial resistant bacteria	(-)
		Crime and insecurity (Kidnapping, Hostage-taking, armed robbery, Militancy)	(-)
		Access to hunting grounds	(-)
		Potential reduction in household water quality and contamination of potable water	(-)
	Drilling and well hook-up	Increase in noise & vibration nuisance	(-)
		Increase in light nuisance	(-)
		Generation of drilling waste	(-)
		Contamination of environment (soils/surface and groundwater)	(-)
		Work related injury/fatality of workforce	(-)
		Non work related injury/fatality of workforce	(-)
		Increase in explosion potential (Well blowout)	(-)
		Increase in diseases STIs, HIV/AIDS	(-)
		Increase in endemic diseases	(-)
		Emergent Infectious diseases resulting from displacement of disease vectors (rodents and monkeys)	(-)
		Loss of biodiversity	(-)
		Potential for development of infrastructures and economic enhancement	(+)
		Increase in road traffic volume & accident potential/injuries	(-)
		Tank leaks	(-)
		Influx of insect pests	(-)
		Opportunity for direct and indirect Employment (Unskilled labour)	(+)
		Opportunity for wealth creation	(+)
		Opportunity for Corporate Social Responsibility	(+)
		Gender imbalance	(-)

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Project Phase	Project Activity	Description of Impact	Nature of Impact
		Potential for skills acquisition	(+)
		Pressure on existing infrastructure and services (Water, Electricity, Recreational facilities, Health facilities, Roads and others)	(-)
		Third party agitation	(-)
		Attack from wild/predatory animals (Snakes, Scorpions)	(-)
		Exposure to radioactive materials	(-)
		Crime and insecurity (Kidnapping, Hostage-taking, armed robbery, Militancy)	(-)
	Well & pipeline testing, Cathodic Protection, Commissioning & Handover	Potential for explosion	(-)
		Exposure to radioactive material	(-)
		Increase in business opportunities	(+)
		Gas flaring from well tests	(-)
		Increase in noise & vibration nuisance	(-)
		Generation of waste (Pigging waste, domestic waste, metal scraps, plastics)	(-)
		Contamination of environment (soils/surface and groundwater)	(-)
		Work related injury/fatality of workforce	(-)
		Non work related injury/fatality of workforce	(-)
		Increase in explosion potential	(-)
		Increase in diseases STIs, HIV/AIDS	(-)
		Increase in endemic diseases (Malaria, Typhoid, RTI)	(-)
		Development of infrastructures and economic enhancement (PGMoU)	(+)
		Increase in road traffic volume & accident potential/injuries	(-)
		Tank leaks	(-)
		Opportunity for direct and indirect Employment (Unskilled labour)	(+)
		Opportunity for wealth creation	(+)
		Loss of Employment (local labour)	(-)
		Third party agitation	(-)
		Attack from wild animals (Snakes, Scorpions)	(-)

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Project Phase	Project Activity	Description of Impact	Nature of Impact
		Crime and insecurity (Kidnapping, Hostage-taking, armed robbery, Militancy)	(-)
		Increased exposure to carcinogenic substances	(-)
		Alcohol and drug abuse	(-)
Demobilization		Increase in road traffic, potential for accidents and injuries	(-)
		Damage to road infrastructure	(-)
		Reduction in air quality	(-)
		Increase in noise and vibration	(-)
		Increase in refined hydrocarbon contents of soil and vegetation	(-)
		Increase in crime rate	(-)
		Contamination of groundwater	(-)
		Soil compaction	(-)
		Waste generation (Scrap metals, Woods, Food waste)	(-)
		Opportunity for contracting	(+)
		Opportunity for direct and indirect Employment (Unskilled labour)	(+)
		Loss of Employment (local labour)	(-)
		Third party agitation	(-)
		Crime and insecurity (Kidnapping, Hostage-taking, armed robbery, Militancy)	(-)
		Increase in RTIs due to dust particles	(-)
		Social dislocation	(-)
		Increased exposure to carcinogenic substances	(-)
Alcohol and drug abuse	(-)		
Operation	Well work-over, Gas production, Pipeline maintenance & replacement	Potential for environmental contamination due to gas leaks	(-)
		Increase in business opportunities	(+)
		Increase in potential for injury/fatality of workforce & third parties	(-)
		Revenue generation for government and SPDC	(+)
		Increase in potential for sabotage of facilities	(-)
		Reduction in gas flaring	(+)

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Project Phase	Project Activity	Description of Impact	Nature of Impact
		Increase in diseases STIs HIV/AIDS	(-)
		Prevalence in endemic diseases (Malaria, Typhoid, RTI)	(-)
		Opportunity for contracting	(+)
		Opportunity for direct and indirect Employment (Unskilled labour)	(+)
		Third party agitation	(-)
		Crime and insecurity (Kidnapping, Hostage-taking, armed robbery, Militancy) and other social vices	(-)
		Waste generation (Scrap metals, Woods, Food waste)	(-)
		Increased exposure to carcinogenic substances	(-)
		Alcohol and drug abuse	(-)
		Contamination of surface water/Sediment	(-)
Decommissioning and abandonment	Flushing of pipelines Vacuum drying of pipeline Capping of pipeline Removal of surface installations Plugging of wells Site restoration Return of land to owner(s)	Increase in potential for soil and water contamination	(-)
		Increase in litigation potential	(-)
		Loss of revenue for Govt. & SPDC	(-)
		Loss of job by community surveillance team	(-)
		Increase in usable land resource to the community	(-)
		Opportunity for contracting	(+)
		Opportunity for direct and indirect Employment (Unskilled labour)	(+)
		Third party agitation	(-)
		Crime and insecurity (Kidnapping, Hostage-taking, armed robbery, Militancy) and other social vices	(-)
		Waste generation (Scrap metals, Woods, Food waste)	(-)
		Increased exposure to carcinogenic substances	(-)
		Alcohol and drug abuse	(-)
		Prevalence of STIs HIV/AIDS	(-)

5.6: Impact Qualification

The identified impacts of the project were qualified based on the following four criteria:

- Positive or negative
- Short-term or long-term
- Reversible or irreversible
- Direct or indirect

Negative impacts are those that adversely affect the biophysical, health and social environments while positive impacts are those, which enhance the quality of the environment. For this study, short term means a period of time less than three months while any period greater than three months is considered long term. By reversible/irreversible, is meant whether the environment can either revert to previous conditions or remain permanent when the activity causing the impact is terminated.

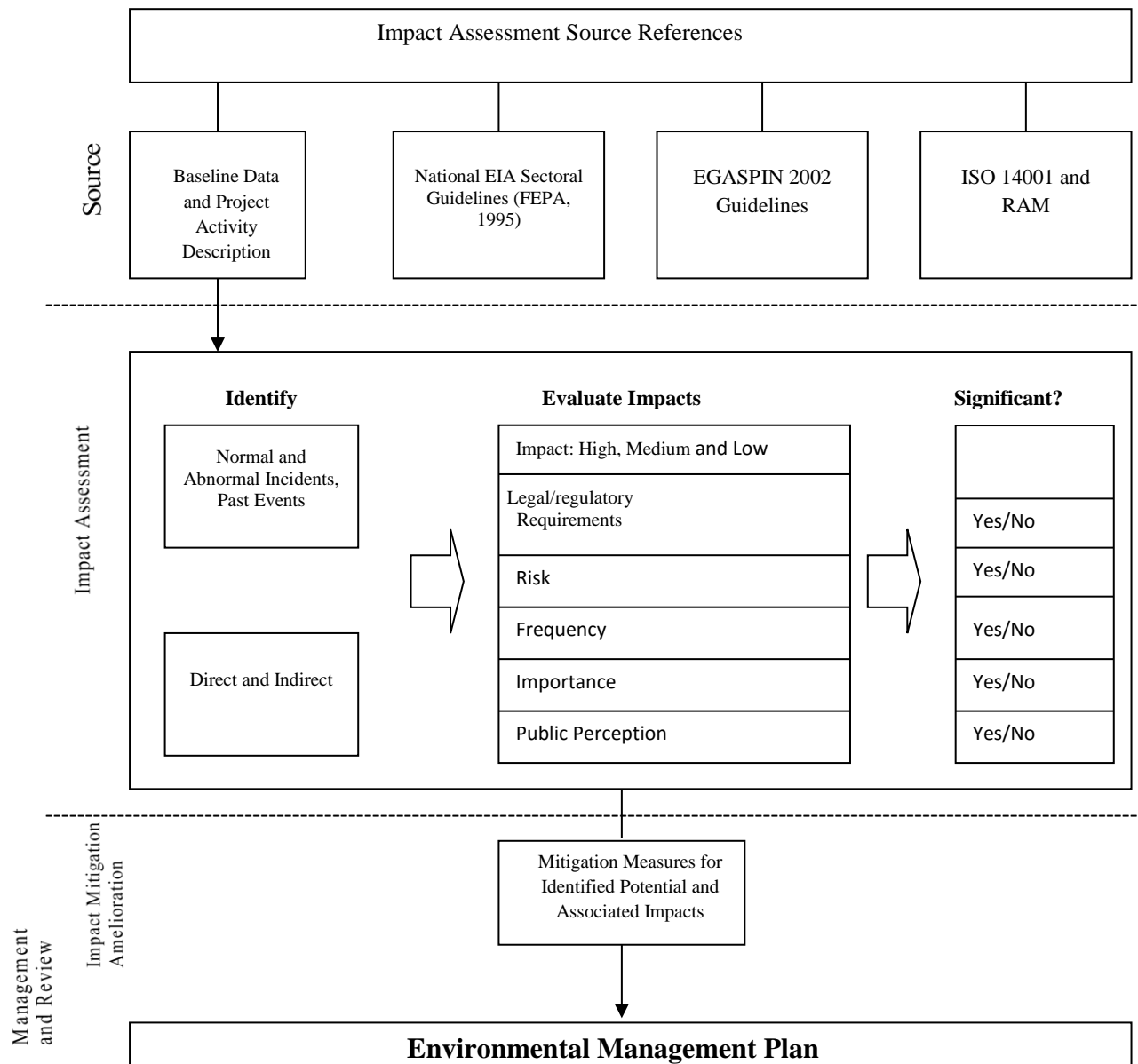


Fig. 5.1: Approach to Impact Assessment

5.7: Risk Assessment for Environmental Consequences

Risk (R) – What is risk/hazard rating based on Risk Assessment Matrix (RAM) (Table 5.3 and Table 5.4). The risks/hazards associated with the project were rated as follows:

- 1= Low risk
- 3 = Medium/intermediate risk
- 5 = High risk

The severity of risks/hazards was further defined as in Table 5.3 and Table 5.4.

Table 5.4: Risk Assessment Matrix

CONSEQUENCES			INCREASING LIKELIHOOD						
					A	B	C	D	E
Severity	People	Assets	Environment	Reputation	Never heard of in the industry	Heard of in the industry	Has happened in the Organization or more than once per year in the industry	Has happened at the location or more than once per year in the organization	Has happened more than once per year at the Location
0	No injury or health effect	No damage	No effect	No impact					
1	Slight injury or health	Slight damage	Slight effect	Slight impact		Low			
2	Minor Injury or health	Minor damage	Minor effect	Minor impact		Risk			
3	Major Injury or health	Moderate damage	Moderate effect	Moderate impact			Medium		
4	PTD or up to 3 fatalities	Major damage	Major effect	Major impact			Risk	High	
5	More than 3 fatalities	Massive damage	Massive effect	Massive impact				Risk	

Table 5.5: Further definition of consequence – severity rating for risk matrix

Severity	Potential Impact	Definition
0	Zero effect	No environmental damage. No change in the environment. No financial consequences.
1	Slight effect	Local environmental damage within the fence and within systems. Negligible financial consequences.
2	Minor effect	Contamination, damage sufficiently large to affect the environment. Single exceedance of statutory or prescribed criteria, single complaint. No permanent effect on the environment

Severity	Potential Impact	Definition
3	Localized effect	Limited loss of discharges of known toxicity. Repeated exceedance of statutory or prescribed limit. Affecting neighborhood
4	Major effect	Severe environmental damage. The company is required to take extensive measures to restore the contaminated environment to its original state. Extended exceedance of statutory or prescribed limits
5	Massive effect	Persistent severe environmental damage or severe nuisance extending over a large area. In terms of commercial or recreational use or nature conservancy, a major economic loss for the company. Constant high exceedance of statutory or prescribed limits.

Source: SIEP (1996)

5.8: Impact Assessment Methodology

Stage one: Classification

The first stage involved in the assessment of impact is impact classification. Impacts are classified as follows:

- Adverse (-) or Beneficial (+) in nature,
- Short term < 3 months (S) or Long term > 3 months (L), and
- Reversible (R) or Irreversible (I).

Adverse impacts are those, which impact negatively on the environmental components while beneficial impacts are those that enhance the quality of the environment. For this study, short term means a period of time less than three months while any period greater than three months is considered long term. By reversible/irreversible, is meant whether the environment can either revert to previous conditions or remain permanent once the activity causing the impact is terminated.

Stage two: Significance

The second stage involves evaluation to determine whether or not the impact is significant. The criteria and weighting scale employed in evaluation are as follows:

- Legal/regulatory requirements (L);
- Risk factor (R);
- Frequency of occurrence of impact (F);
- Importance of impact on an affected environmental component (I); and
- Public perception/interest (P).

The quantification scale of 0, 1, 3 and 5 was used. This is a modification of the arbitrary scale proposed by Vesilind, *et al.* (1994). The ratings are as described below and are adapted from The International Organization for Standardization (ISO, 14001) – Environmental Management System Approach.

- **Legal/Regulatory Requirements (L) – Is there a legal/regulatory requirement or a permit required?**
 - 0 = There is no legal/regulatory requirement
 - 3 = There is legal/regulatory requirement
 - 5 = There is a legal/regulatory requirement and permit required
- **Risk Factor (R) – What is the risk/hazard rating based on the Risk Assessment Matrix?**
 - 1 = Low risk
 - 3 = Intermediate risk
 - 5 = High risk
- **Frequency of Impact (F) – What is the frequency rating of impact based on the Risk Assessment Matrix?**
 - 1 = Low frequency (rare)
 - 3 = Intermediate frequency (likely)
 - 5 = High frequency (very likely)
- **Public interest/perception (P) – What is the rating of public perception and interest in proposed project and impacts based on consultation with stakeholders?**
 - 1 = Low interest/perception
 - 3 = Intermediate interest/perception
 - 5 = High interest/perception
- **Importance of affected environmental components and impacts (I) – What is the rating of importance based on consensus of opinions?**
 - 1 = Low
 - 3 = Medium
 - 5 = High

This approach combines the following factors in assessing the overall impact rating of the project on the environment:

- The sensitivity/vulnerability of the ecosystem components;
- The productivity evaluation/rating of the ecosystem components;
- Knowledge of the possible interactions between the proposed project and the environment;
- Envisaged sustainability of the project environment;
- The economic value of the proposed project activities; and

- Projected duration of the impact of each project activity on various environmental components.

The frequency of occurrence of each impact was determined from historical records while the importance of affected environmental component was determined through consultation and consensus of opinions. The perception of the communities and the general public on each potential impact and its effects as reported in the various reports reviewed were determined through consultation with the communities and consensus of opinions of environmental professionals. The overall impact rating is determined as shown in Table 5.6. The potential and associated impacts of the project are presented in Table 5.7.

Table 5.6: Impact Value and Rating

Impact value	Cut off values	Impact Rating
L+R+F+I+P	<8	Low
L+R+F+I+P	≥8 but <15	Medium
L+R+F+I+P	≥15	High
F + I	≥6	
P	= 5	
Positive		Positive

Table 5.7: Potential and Associated Impacts Identification, Qualification, Quantification and Rating

Project phase	Project activity	Description of impact	IMPACT QUALIFICATION									IMPACT QUANTIFICATION					TOTAL	F + I	IMPACT RATING
			ADVERSE	BENEFICIAL	DIRECT	INDIRECT	SHORT TERM (<3 months)	LONG TERM (>3 Months)	REVERSIBLE	IRREVERSIBLE	LOCAL OR WIDESPREAD	LEGAL	RISK FACTOR	FREQUENCY	IMPORTANCE	PUBLIC INTEREST			
Pre-mobilization	<ul style="list-style-type: none"> • Consultation, • Land acquisition and • Compensation, Resolution of legacy issues 	Increase in project awareness	X	X	X	X	X		X		L	3	1	5	5	5	19	10	HIGH
		Anticipated Loss of land associated resources	X		X			X	X		L	3	3	3	5	5	19	8	HIGH
		Financial enhancement		X	X	X	X		X		L	-	-	-	-	-	-	-	P
		Third party agitation	X		X		X	X	X		L/W	0	5	5	5	5	20	10	HIGH
Mobilization	<ul style="list-style-type: none"> • Movement of equipment and personnel, • Rig movement 	Loss of livelihood	X		X		X	X	X		L	0	3	3	5	3	14	8	HIGH
		Increase in road traffic, potential for accidents and injuries	X		X		X		X	X	L/W	3	3	3	3	5	17	6	HIGH
		Damage to road infrastructure	X		X		X		X		L	0	3	5	3	5	16	8	HIGH
		Influx of people causing Pressure on health and other Infrastructure	X		X		X	X	X		L	0	3	3	3	5	14	6	HIGH
		Increase in sexually transmitted disease	X		X		X	X	X	X	L	0	3	3	3	3	12	6	HIGH

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Project phase	Project activity	Description of impact	IMPACT QUALIFICATION									IMPACT QUANTIFICATION					TOTAL	F + I	IMPACT RATING
			ADVERSE	BENEFICIAL	DIRECT	INDIRECT	SHORT TERM (<3 months)	LONG TERM (>3 Months)	REVERSIBLE	IRREVERSIBLE	LOCAL OR WIDESPREAD	LEGAL	RISK FACTOR	FREQUENCY	IMPORTANCE	PUBLIC INTEREST			
		and other communicable diseases																	
		Reduction in air quality	X		X		X	X	X		L/W	3	5	5	5	5	23	10	HIGH
		Loss of vegetation and wildlife	X		X		X	X	X		L	0	1	3	3	3	10	6	HIGH
		Habitat fragmentation	X		X		X	X	X	X	L	0	1	3	3	3	10	6	HIGH
		Loss of aquatic species (Fisheries, Planktons and benthic fauna)	X		X		X		X		L	3	3	3	3	3	15	6	HIGH
		Distortion of aquatic environment (physical components)	X		X		X		X		L	3	3	3	3	3	15	6	HIGH
		Increase in noise and vibration	X		X			X	X		L	3	3	3	3	3	15	6	HIGH
		Increase in refined hydrocarbon contents of soil and vegetation	X		X			X	X		L/W	3	3	3	3	1	13	6	HIGH
		Increase in crime rate	X		X		X	X		X	L	0	3	1	3	3	10	4	MEDIUM

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Project phase	Project activity	Description of impact	IMPACT QUALIFICATION									IMPACT QUANTIFICATION					TOTAL	F + I	IMPACT RATING
			ADVERSE	BENEFICIAL	DIRECT	INDIRECT	SHORT TERM (<3 months)	LONG TERM (>3 Months)	REVERSIBLE	IRREVERSIBLE	LOCAL OR WIDESPREAD	LEGAL	RISK FACTOR	FREQUENCY	IMPORTANCE	PUBLIC INTEREST			
		Loss of cultural/heritage sites	X		X			X	X	X	L	3	3	1	3	3	13	4	MEDIUM
		Contamination of groundwater	X		X		X		X		L	3	3	1	5	3	15	6	HIGH
		Soil compaction	X		X			X		X	L	0	1	1	3	1	6	4	LOW
		Increase in waste	X		X			X	X		L	3	3	3	3	3	15	6	HIGH
Construction	Wells/locations/pipelines <ul style="list-style-type: none"> Route & location clearing Dredging, Pipeline river crossing, Pilling, Concrete and asphalt works, Excavation Backfilling Pipeline coating Stringing & welding; NDT and cathodic protection Base camp activities 	Increase in respiratory tract infection	X		X		X		X		L	3	3	5	5	5	21	10	HIGH
		Increase in population due to influx of persons	X	X	X	X	X	X	X		L	0	3	5	3	3	14	8	HIGH
		Increase in social vices (Alcohol and drug abuse, CSWs)	X		X		X		X		L	0	5	3	5	3	16	8	HIGH
		Crime and insecurity (Kidnapping, Hostage-taking, armed robbery, Militancy)	X		X		X		X		L	0	5	5	5	5	20	10	HIGH
		Injury/fatality of workforce and/or third party	X		X		X	X	X	X	L	3	5	3	3	3	17	6	HIGH

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Project phase	Project activity	Description of impact	IMPACT QUALIFICATION									IMPACT QUANTIFICATION					TOTAL	F + I	IMPACT RATING
			ADVERSE	BENEFICIAL	DIRECT	INDIRECT	SHORT TERM (<3 months)	LONG TERM (>3 Months)	REVERSIBLE	IRREVERSIBLE	LOCAL OR WIDESPREAD	LEGAL	RISK FACTOR	FREQUENCY	IMPORTANCE	PUBLIC INTEREST			
		Road traffic disruption	X		X		X	X	X		L	0	3	5	5	5	18	10	HIGH
		Increase in volume of wastes	X		X		X	X	X		L	3	3	5	5	5	21	10	HIGH
		Increase in employment/business opportunities		X	X	X	X	X	X		L/W	-	-	-	-	-	-	-	P
		Shift from traditional occupations	X		X		X		X		L	0	3	5	3	3	14	8	HIGH
		Inflation	X		X		X	X	X		L	0	3	5	3	3	14	8	HIGH
		Gender imbalance	X		X		X	X	X		L	0	1	5	3	3	12	8	HIGH
		Potential for skills acquisition		X	X	X	X	X		X	L/W	-	-	-	-	-	-	-	P
		Pressure on existing infrastructure and services (Water, Electricity, Recreational facilities, Health facilities, Roads and others)	X		X		X		X		L	0	3	5	5	3	16	10	HIGH
		Increase in communicable diseases, STIs HIV/AIDS	X		X			X	X	X	L/W	0	5	5	5	5	20	10	HIGH

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Project phase	Project activity	Description of impact	IMPACT QUALIFICATION									IMPACT QUANTIFICATION					TOTAL	F + I	IMPACT RATING
			ADVERSE	BENEFICIAL	DIRECT	INDIRECT	SHORT TERM (<3 months)	LONG TERM (>3 Months)	REVERSIBLE	IRREVERSIBLE	LOCAL OR WIDESPREAD	LEGAL	RISK FACTOR	FREQUENCY	IMPORTANCE	PUBLIC INTEREST			
		Change in topography	X		X			X		X	L	0	3	5	3	3	14	8	HIGH
		Change in hydrology (groundwater)	X		X		X	X	X	X	L	3	3	1	3	3	13	4	MEDIUM
		Surface water pollution/distortion (increase in turbidity and Total Suspended Solids)	X		X		X		X		L	3	5	5	5	5	23	10	HIGH
		Soil pollution	X		X		X	X	X		L	3	3	3	3	3	15	6	HIGH
		Loss of biodiversity and Distortion of food chain (Economic trees)	X		X		X	X	X	X	L	3	3	3	3	3	15	6	HIGH
		Impairment/Loss of aquatic life (Loss of juvenile fishes due to gill damage from silt particles)	X		X		X	X	X		L	3	3	3	5	5	19	8	HIGH
		Increase in disease vectors	X		X			X	X		L	0	5	3	3	3	14	6	HIGH
		Blockage of natural water courses	X		X		X		X		L	0	3	3	5	5	16	8	HIGH
		Increase in road traffic/ potential for	X		X			X	X	X	L	0	5	5	5	3	18	10	HIGH

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			ADVERSE	BENEFICIAL	DIRECT	INDIRECT	SHORT TERM (<3 months)	LONG TERM (>3 Months)	REVERSIBLE	IRREVERSIBLE	LOCAL OR WIDESPREAD	LEGAL	RISK FACTOR	FREQUENCY	IMPORTANCE	PUBLIC INTEREST			
		accidents and injuries																	
		Food insecurity	x		x		x	x	x	X	L	0	3	5	5	3	16	10	HIGH
		Erosion	X		X	X	X	X	X		L	0	5	5	5	5	20	10	HIGH
		Loss of indigenous languages	X		X	X		X		X	L/W	0	1	1	3	1	6	4	LOW
		Loss of fish breeding sites and migratory routes	X		X		X		X		L	0	3	3	3	3	12	6	HIGH
		Noise and vibration	X		X			X	X		L	3	3	5	3	3	17	8	HIGH
		Reduction in air quality	X		X		X		X		L	3	3	3	3	5	17	6	HIGH
		Opportunity for direct and indirect Employment		X	X	X	X	X	X		L/W	-	-	-	-	-	-	-	P
		Opportunity for wealth creation		X	X	X	X	X	X		L/W	-	-	-	-	-	-	-	P
		Opportunity for Corporate Social Responsibility		X	X	X	X	X	X		L/W	-	-	-	-	-	-	-	P
		Exposure to radioactive materials	X		X	X	X		X		L	3	5	3	3	3	17	6	HIGH
		Third party agitation	X		X		X	X	X		L/W	0	5	5	5	3	18	10	HIGH

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			ADVERSE	BENEFICIAL	DIRECT	INDIRECT	SHORT TERM (<3 months)	LONG TERM (>3 Months)	REVERSIBLE	IRREVERSIBLE	LOCAL OR WIDESPREAD	LEGAL	RISK FACTOR	FREQUENCY	IMPORTANCE	PUBLIC INTEREST			
		Potential attack from wild/predatory animals (Snakes, Scorpions)	X		X		X		X	X	L	0	3	1	5	3	12	6	HIGH
		Increase in exposure to transborder diseases (Zika virus, Ebola, Birdflu, SARS), Antimicrobial resistant bacteria	X		X	X	X	X	X	X	L/W	0	3	3	5	5	16	8	HIGH
		Crime and insecurity (Kidnapping, Hostage-taking, armed robbery, Militancy)	X		X		X		X	X	L	0	5	3	5	5	18	8	HIGH
		Access to hunting grounds	X		X	X	X	X	X	X	L	0	3	1	3	1	8	4	MEDIUM
		Potential reduction in household water quality and contamination of potable water	X		X		X	X	X		L	3	5	3	5	3	19	8	HIGH
		Temporary disruption of local fishing/harvesting activities.	X		X	X	X	X	X	X	L	0	3	1	3	1	8	4	MEDIUM

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		Acidification of the soil and surface water as a result of deposition of dredge spoils on the banks of the river	X		X	X	X	X	X	X	L	3	3	1	3	1	11	4	MEDIUM
		Spoil disposal will smother epifauna and impair surface drainage especially in wetland areas	X		X	X	X	X	X	X	L	0	3	1	3	1	8	4	MEDIUM
		Disaggregation of benthic habitats and loss of benthic organisms.	X		X	X	X	X	X	X	L	0	3	1	3	1	8	4	MEDIUM
		Disturbance of riverbed topography and re-suspension of fine sediments and bottom materials	X		X	X	X	X	X	X	L	0	3	1	3	1	8	4	MEDIUM
		Disturbance of riverbed topography	X		X	X	X	X	X	X	L	0	3	1	3	1	8	4	MEDIUM
	Drilling and well hook-up	Increase in noise & vibration nuisance	X		X		X	X	X	X	L	3	3	3	5	5	19	8	HIGH
		Increase in light nuisance	X		X	X	X		X		L	0	3	3	3	1	10	6	HIGH

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			ADVERSE	BENEFICIAL	DIRECT	INDIRECT	SHORT TERM (<3 months)	LONG TERM (>3 Months)	REVERSIBLE	IRREVERSIBLE	LOCAL OR WIDESPREAD	LEGAL	RISK FACTOR	FREQUENCY	IMPORTANCE	PUBLIC INTEREST			
		Generation of drilling waste	X		X		X		X		L	5	5	5	5	5	25	10	HIGH
		Contamination of environment (soils/surface and groundwater)	X		X	X	X		X		L	3	3	3	3	3	15	6	HIGH
		Work related injury/fatality of workforce	X		X		X	X	X	X	L	3	3	3	5	5	19	8	HIGH
		Non work related injury/fatality of workforce	X		X		X	X	X	X	L	0	3	3	3	5	14	6	HIGH
		Increase in explosion potential (Well blowout)	X		X	X	X		X	X	W	0	5	1	5	5	16	6	HIGH
		Increase in diseases STIs, HIV/AIDS	X		X		X	X	X	X	L	0	5	5	5	5	20	10	HIGH
		Increase in endemic diseases	X		X		X	X	X	X	L/W	0	5	3	5	5	18	8	HIGH
		Emergent Infectious diseases resulting from displacement of disease vectors (rodents and monkeys)	X		X	X	X	X	X	X	L/W	0	3	3	5	5	16	8	HIGH
		Loss of biodiversity	X		X		X	X	X	X	L	0	3	3	3	3	12	6	HIGH

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			ADVERSE	BENEFICIAL	DIRECT	INDIRECT	SHORT TERM (<3 months)	LONG TERM (>3 Months)	REVERSIBLE	IRREVERSIBLE	LOCAL OR WIDESPREAD	LEGAL	RISK FACTOR	FREQUENCY	IMPORTANCE	PUBLIC INTEREST			
		Potential for development of infrastructures and economic enhancement		X	X		X	X		X	L	-	-	-	-	-	-	P	
		Increase in road traffic volume & accident potential/injuries	X		X		X	X	X	X	L	0	5	3	3	3	14	6	HIGH
		Tank leaks	X		X		X		X		L	3	5	3	5	3	19	8	HIGH
		Influx of insect pests	X		X	X	X	X	X	X	L	0	5	5	5	5	20	10	HIGH
		Opportunity for direct and indirect Employment (Unskilled labour)		X	X		X		X		L	-	-	-	-	-	-	-	P
		Opportunity for wealth creation		X	X	X	X	X	X		L	-	-	-	-	-	-	-	P
		Opportunity for Corporate Social Responsibility		X	X	X	X	X	X	X	L	-	-	-	-	-	-	-	P
		Gender imbalance	X		X		X	X	X		L	0	1	5	3	3	12	8	HIGH
		Potential for skills acquisition		X	X	X	X	X	X		L	-	-	-	-	-	-	-	P

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			ADVERSE	BENEFICIAL	DIRECT	INDIRECT	SHORT TERM (<3 months)	LONG TERM (>3 Months)	REVERSIBLE	IRREVERSIBLE	LOCAL OR WIDESPREAD	LEGAL	RISK FACTOR	FREQUENCY	IMPORTANCE	PUBLIC INTEREST			
		Pressure on existing infrastructure and services (Water, Electricity, Recreational facilities, Health facilities, Roads and others)	X		X		X		X		L	0	3	5	5	3	16	10	HIGH
		Third party agitation	X		X		X	X	X		L/W	0	5	5	5	3	18	10	HIGH
		Attack from wild/predatory animals (Snakes, Scorpions)	X		X		X	X	X		L	0	1	3	3	3	10	6	HIGH
		Exposure to radioactive materials	X		X	X	X		X		L	3	5	3	3	3	17	6	HIGH
		Crime and insecurity (Kidnapping, Hostage-taking, armed robbery, Militancy)	X		X		X		X		L	0	5	5	5	5	20	10	HIGH
	Well & pipeline testing, Hydrotesting,	Potential for explosion	X		X		X	X	X	X	L	0	5	5	5	3	18	10	HIGH

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		Discharge of untreated test water into the receiving environment	X		X	X	X	X	X	X	L	0	3	1	3	1	8	4	MEDIUM
	Cathodic Protection,	Exposure to radioactive material	X		X		X		X		L	3	5	3	5	3	19	8	HIGH
	Commissioning & Handover	Increase in Business opportunities		X	X	X	X	X	X		L/W	-	-	-	-	-	-	-	P
		Gas flaring from well tests	X		X		X		X		L	3	5	5	5	5	23	10	HIGH
		Increase in noise & vibration nuisance	X		X		X	X	X	X	L	3	3	3	5	5	19	8	HIGH
		Generation of waste (Pigging waste, domestic waste, metal scraps, plastics)	X		X			X	X		L	3	3	3	3	3	15	6	HIGH
		Contamination of environment (soils/surface and groundwater)	X		X	X	X		X		L	3	3	3	3	3	15	6	HIGH
		Work related injury/fatality of workforce	X		X		X	X	X	X	L	3	3	3	5	5	19	8	HIGH

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		Non work related injury/fatality of workforce	X		X		X	X	X	X	L	0	3	3	3	5	14	6	HIGH
		Increase in explosion potential	X		X		X	X	X	X	L	0	5	5	5	3	18	10	HIGH
		Increase in diseases STIs, HIV/AIDS	X		X		X	X	X	X	L	0	3	3	3	3	12	6	HIGH
		Increase in endemic diseases (Malaria, Typhoid, RTI)	X		X		X	X	X	X	L	0	3	3	3	3	12	6	HIGH
		Development of infrastructures and economic enhancement (GMoU)		X	X	X	X	X	X		L/W	-	-	-	-	-	-	-	P
		Increase in road traffic volume & accident potential/injuries	X		X		X	X	X	X	L	0	5	3	3	3	14	6	HIGH
		Tank leaks	X		X		X		X		L	3	5	3	5	3	19	8	HIGH
		Opportunity for direct and indirect Employment (Unskilled labour)		X	X		X		X		L	-	-	-	-	-	-	-	P
		Opportunity for wealth creation		X	X	X	X	X	X		L	-	-	-	-	-	-	-	P

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			ADVERSE	BENEFICIAL	DIRECT	INDIRECT	SHORT TERM (<3 months)	LONG TERM (>3 Months)	REVERSIBLE	IRREVERSIBLE	LOCAL OR WIDESPREAD	LEGAL	RISK FACTOR	FREQUENCY	IMPORTANCE	PUBLIC INTEREST			
		Loss of Employment (local labour) (Boom burst cycle)	X		X	X	x		x		L	3	5	5	3	5	21	8	HIGH
		Third party agitation	X		X		X	X	X		L/W	0	5	5	5	3	18	10	HIGH
		Attack from wild animals (Snakes, Scorpions)	X		X		X	X	X		L	0	1	3	3	3	10	6	HIGH
		Crime and insecurity (Kidnapping, Hostage-taking, armed robbery, Militancy)	X		X		X		X		L	0	5	5	5	5	20	10	HIGH
		Increased exposure to carcinogenic substances	X		X		X		X		L	3	5	3	5	3	19	8	HIGH
		Alcohol and drug abuse	X		X			X	X	X		L/W	0	5	5	5	5	20	10
Demobilization		Increase in road traffic, potential for accidents and injuries	X		X		X	X	X	X	L	0	5	3	3	3	14	6	HIGH
		Damage to road infrastructure	X		X		X	X	X	X	L	0	5	3	3	3	14	6	HIGH
		Impairment in air quality	X		X		X		X		L	3	3	3	3	5	17	6	HIGH

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		Increase in noise and vibration	X		X		X	X	X	X	L	3	3	3	5	5	19	8	HIGH
		Increase in refined hydrocarbon contents of soil and vegetation	X		X			X	X		L/W	3	3	3	3	1	13	6	HIGH
		Increase in crime rate	X		X		X		X		L	0	5	5	5	5	20	10	HIGH
		Contamination of groundwater	X		X			X	X		L	3	3	3	3	3	15	6	HIGH
		Soil compaction	X		X			X		X	L	0	1	1	3	1	6	4	LOW
		Waste generation (Scrap metals, Woods, Food waste)	X		X			X	X		L	3	3	3	3	3	15	6	HIGH
		Opportunity for contracting		X	X	X	X	X	X		L	-	-	-	-	-	-	-	P
		Opportunity for direct and indirect Employment (Unskilled labour)		X	X	X	X	X	X		L	-	-	-	-	-	-	-	P
		Loss of Employment (local labour)	X		X	X	x		x		L	3	5	5	3	5	21	8	HIGH
		Third party agitation	X		X		X	X	X		L/W	0	5	5	5	3	18	10	HIGH
		Crime and insecurity (Kidnapping,	X		X		X		X		L	0	5	5	5	5	20	10	HIGH

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		Hostage-taking, armed robbery, Militancy)																	
		Increase in RTIs due to dust particles	X		X		X	X	X	X	L	0	3	3	3	3	12	6	HIGH
		Social dislocation	x		x		x		x		L	0	5	5	5	5	20	10	HIGH
		Increased exposure to carcinogenic substances	X		X		X		X		L	0	5	3	5	3	16	8	HIGH
		Alcohol and drug abuse	X		X		X		X		L	0	3	3	3	3	12	6	HIGH
Operation	Well work-over, Gas production,	Potential for environmental contamination due to gas leaks	X		X		X		X		L	3	3	3	3	5	17	6	HIGH
	Pipeline maintenance & replacement	Increase in business opportunities		X	X	X	X	X	X		L	-	-	-	-	-	-	-	P
		Increase in potential for injury/fatality of workforce & third parties	X		X		X	X	X	X	L	0	5	3	3	3	14	6	HIGH
		Revenue generation for government and SPDC		X	X	X	X	X	X		L	-	-	-	-	-	-	-	P

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		Increase in potential for sabotage of facilities	X		X		X	X	X	X	L	0	3	3	3	3	12	6	HIGH
		Reduction in gas flaring		X	X	X	X	X	X		L	-	-	-	-	-	-	-	P
		Increase in diseases STIs HIV/AIDS	X		X		X	X	X	X	L	0	3	3	3	3	12	6	HIGH
		Prevalence in endemic diseases (Malaria, Typhoid, RTI)	X		X		X	X	X	X	L	0	3	3	3	3	12	6	HIGH
		Opportunity for contracting		X	X	X	X	X	X		L	-	-	-	-	-	-	-	P
		Opportunity for direct and indirect Employment (Unskilled labour)		X	X	X	X	X	X		L	-	-	-	-	-	-	-	P
		Third party agitation	X		X		X	X	X		L/W	0	3	3	3	3	12	6	HIGH
		Crime and insecurity (Kidnapping, Hostage-taking, armed robbery, Militancy) and other social vices	X		X		X		X		L	0	5	5	5	5	20	10	HIGH

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		Waste generation (Scrap metals, Woods, Food waste)	X		X			X	X		L	3	3	3	3	3	15	6	HIGH	
		Increased exposure to carcinogenic substances	X		X		X		X		L	0	5	3	5	3	16	8	HIGH	
		Alcohol and drug abuse	X		X		X		X		L	0	3	3	3	3	12	6	HIGH	
		Contamination of surface water/Sediment	X		X	X	X		X		L	3	3	3	3	3	15	6	HIGH	
Decommissioning and abandonment	Flushing of pipelines	Increase in potential for soil and water contamination	X		X	X	X		X		L	3	3	3	3	3	15	6	HIGH	
	Vacuum drying of pipeline	Increase in litigation potential	X		X	X	X	X	X		L/W	3	3	3	3	3	15	6	HIGH	
	Capping of pipeline	Loss of revenue for Govt. & SPDC	X		X		X	X		X		L/W	0	5	3	3	3	14	6	HIGH
	Removal of surface installations	Loss of job by community surveillance team	X		X	X	X		X		L	3	5	5	3	5	21	8	HIGH	
	Plugging of wells	Increase in usable land resource to the community		X	X		X		X		L	-	-	-	-	-	-	-	P	
	Site restoration																			
	Return of land to owner(s)																			

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		Opportunity for contracting		X	X		X		X		L	-	-	-	-	-	-	-	P
		Opportunity for direct and indirect Employment (Unskilled labour)		X	X		X		X		L	-	-	-	-	-	-	-	P
		Third party agitation	X		X		X	X	X		L/W	0	3	3	3	3	12	6	HIGH
		Crime and insecurity (Kidnapping, Hostage-taking, armed robbery, Militancy) and other social vices	X		X		X		X		L	0	5	5	5	5	20	10	HIGH
		Waste generation (Scrap metals, Woods, Food waste)	X		X			X	X		L	3	3	3	3	3	15	6	HIGH
		Increased exposure to carcinogenic substances	X		X		X		X		L	0	5	3	5	3	16	8	HIGH
		Alcohol and drug abuse	X		X		X		X		L	0	3	3	3	3	12	6	HIGH
		Prevalence of STIs HIV/AIDS	X		X		X	X	X		L	0	3	3	3	3	12	6	HIGH

5.9: Existing impacts arising from the interface between the Enwhe field and the Gbaran Central Processing Facility

Three NAG wells in the West location will be hooked up to the Enwhe West manifold which will be installed near the Enwhe West cluster well location. The combined flow from the six wells will be bulk flowed from Enwhe West manifold via a 36 km long, 12’’ bulkline to the Gbaran CPF. The interface between the Enwhe field and the Gbaran CPF are Wells and the Pipeline. In evaluating the existing impacts that will arise from the interface, the existing impacts of the Gbaran CPF will be evaluated using the ECM 2016 data for the most sensitive environmental receptors (Air quality and noise, surface water and groundwater quality). The existing impacts arising from the interface between the Enwhe field and the Gbaran Central Processing Facility are presented in **Table 5.9a to Table 5.9b**.

Methodology for Quantification and Evaluation of Existing Impacts of the Gbaran CPF and their Significance

The impact assessment of existing facilities involved impact identification, qualification, quantification and significance rating. *Rau and Wooten’s scheme* was used for the impact assessment (*Rau and Wooten, 1980*). The assessment of the environmental impacts of the facilities was quantified and evaluated using standard laboratory analytical methods to assess the magnitude of the impact to the environment. Interpretation of these data was benchmarked with the available data from the Environmental Compliance Monitoring report for the Gbaran Infill Project, 2016, National/International standards/limits and control data collected during the field activities. Furthermore, the evaluation determined the likely receptors in the environment and established the source-receptor pathways. In addition, it determined the current and likely future risks posed by the facilities. The components of the environment that could be affected by the Gbaran CPF are shown in Table 5.8a.

Table 5.8a: Environmental Components

S/No	Components of Environment	Impact Indicators
1	Air Quality and Noise	Particulate, NO _x , SO ₂ , CO, VOCs, H ₂ S, CH ₄
2	Groundwater quality	Colour, alkalinity, TDS, TSS, Turbidity, EC, THC, pH, DO, BOD ₅ , COD, Oil & Grease, PAH, TPH, BTEX, NO ₃ ⁻ , PO ₄ ³⁻ , SO ₄ ²⁻ , Na ⁺ , K ⁺ , Ca ²⁺ , Mg ²⁺ . Heavy metals (Fe, Cu, Mn, Cd, Cr, Ni, V, Pb, Zn, Hg).

The criteria and weighting scale (Table 5.8) used in evaluating this significance are based on *Rau and Wooten’s scheme* (*Rau and Wooten, 1980*).

$$IM = \frac{\text{Control result /Standard value} - \text{Obtained result}}{\text{Control result /Standard value}} \times 100$$

The above equation was modified in this study as:

$$IM = \frac{\text{Gbaran Infill Control (ECM, 2016)} - \text{Gbaran Infill ECM 2016}}{\text{ECM 2016}} \times 100$$

Where,

IM = Impact Magnitude

Values obtained by the above operation were first expressed as a percentage, thereafter the scale was reduced to 1 – 5 as summarized in Table 5.8.

Table 5.8b: Impact Evaluation and Weighting Scheme

Impact Magnitude	Impact Evaluation	Impact Classification
0 – 20%	1	Negligible
21 – 40%	2	Low
41 – 60%	3	Medium
61 – 80%	4	High
>80 %	5	Severe

For this study, positive values were ignored while negative values were considered for impact assessment. Medium to severe significant negative impacts were judged to require mitigation.

In using this classification scheme,

- Negligible = very minimal variation between the mean value of control and that of the impacted area;
- Low = minimal variation between the mean value of control and that of the impacted area;
- Medium = moderately significant variation between the mean value of control and that of the impacted area;
- High = significant variation between the mean value of control and that of the impacted area;
- Severe = highly significant variation between the mean value of control and that of the impacted area.

It should be noted that the ratings used here are only reckoned with in relation to the values in control, and primarily governed by the control values rather than regulatory standards.

Air quality and noise

The study established no impact of the Gbaran Central Processing Facility (CPF) on the ambient airshed in the Wet and dry season (Table 5.9a). In the dry season, the gaseous pollutants (SO₂, NO₂, CO, VOC, H₂S and heavy metals) around the CPF compared favourably with the control stations as the concentrations were below the equipment detection limits. Similarly, in the dry season, only the Suspended Particulate Matter (SPM) were classified as Low on the *Rau and Wooten* weighing scale. The gaseous pollutants in both climatic regimes complied with the DPR limits for daily average/mean values. Long term monitoring (as part of the compliance monitoring report) from 2013 to 2016 around the CPF show values that are consistently compliant with DPR limits.

Table 5.9a: Evaluation (Scale) of Air Quality and Noise Impacts of the Gbaran CPF in the Wet and Dry season

Parameters	Dry season					Wet season				
	CPF	Control	Impact Assessment	Scale	Impact Classification	CPF	Control	Impact Assessment	Scale	Impact Classification
SO ₂ (µg/m ³)	<26.2	<26.2	0	1	Negligible	<26.2	<26.2	0	1	Negligible
NO ₂ (µg/m ³)	<18.8	<18.8	0	1	Negligible	<18.8	<18.8	0	1	Negligible
CO (µg/m ³)	<1.00	<1.00	0	1	Negligible	<1.00	<1.00	0	1	Negligible
SPM (µg/m ³)	2.89	2.66	-8.65	1	Negligible	4.17	3.37	-23.74	2	Low
VOC (µg/m ³)	<1.00	<1.00	0	1	Negligible	<1.00	<1.00	0	1	Negligible
H ₂ S (µg/m ³)	<13.9	<13.9	0	1	Negligible	<13.9	<13.9	0	1	Negligible
O ₃ (µg/m ³)	<0.10	<0.10	0	1	Negligible	<0.10	<0.10	0	1	Negligible
Pb (µg/m ³)	<0.10	<0.10	0	1	Negligible	<0.10	<0.10	0	1	Negligible
Cr (µg/m ³)	<0.10	<0.10	0	1	Negligible	<0.10	<0.10	0	1	Negligible
Cd (µg/m ³)	<0.10	<0.10	0	1	Negligible	<0.10	<0.10	0	1	Negligible
Noise dB(A) (Flare 1)	69.16	NM	NA	NA	NA	69.07	NM	NA	NA	NA
Noise dB(A) (Flare 2)	70.02	NM	NA	NA	NA	68.28	NM	NA	NA	NA
Noise dB(A) (Gas turbine Generator)	65.47	NM	NA	NA	NA	62.44	NM	NA	NA	NA
Noise dB(A) (Compressor)	63.64	NM	NA	NA	NA	NM	NM	NA	NA	NA

Groundwater quality

The evaluation of magnitude of impacts on the groundwater quality is presented in **Table 5.9b**. The groundwater quality parameters in the dry and wet season were rated **Negligible** on the *Rau and Wooten* impact classification scale. The consistent values in both climatic regimes maybe attributed to uniformity in the nature and composition of the unconfined aquifer. The groundwater values complied with the Nigerian Standard for Drinking Water Quality standards.

Table 5.9b: Evaluation (Scale) of Groundwater of the Gbaran CPF in the Wet and Dry season

Parameters	Dry season					Wet Season				
	CPF	EER baseline Data	Impact Assessment	Scale	Impact Classification	CPF	EER baseline Data	Impact Assessment	Scale	Impact Classification
pH	7.6	6.73	-12.93	1	Negligible	6.7	6.73	0.45	NA	
Oil and Grease (mg/L)	<1.00	<1.00	0	1	Negligible	<1.00	<0.05	0	1	Negligible
TPH (mg/L)	<1.00	<1.00	0	1	Negligible	<1.00	<0.01	0	1	Negligible
Cr (mg/L)	<0.05	<0.05	0	1	Negligible	0.06	<0.05	0	1	Negligible
Pb (mg/L)	<0.05	<0.05	0	1	Negligible	<0.05	<0.05	0	1	Negligible
Ni (mg/L)	0.07	<0.05	0	1	Negligible	0.06	<0.05	0	1	Negligible
V (mg/L)	<0.001	<0.001	0	1	Negligible	<0.001	<0.001	0	1	Negligible
THC (mg/L)	<1.00	<0.05	0	1	Negligible	<1.00	<0.05	0	1	Negligible
PAH (mg/L)	<0.001	<0.01	0	1	Negligible	<0.0001	<0.01	0	1	Negligible

5.10: Cumulative Impacts

The cumulative impacts is regarded as a combination of existing impacts derived from operations of the Gbaran Central Processing Facility and potential and associated impacts from the proposed project activities in the Enwhe field. The cumulative impacts in the Enwhe field is presented in **Table 5.10**.

Table 5.10: Cumulative impacts/effects of the Enwhe FDP

Project phase	Project activity	Description of impact	Potential and Associated Impact (ISO 14001 method)
Pre-mobilization	<ul style="list-style-type: none"> • Consultation, • Land acquisition and • Compensation, Resolution of legacy issues 	Increase in project awareness	HIGH
		Anticipated Loss of land associated resources	HIGH
		Financial enhancement	P
		Third party agitation	HIGH
Mobilization	<ul style="list-style-type: none"> • Movement of equipment and personnel, • Rig movement 	Loss of livelihood	HIGH
		Increase in road traffic, potential for accidents and injuries	HIGH
		Damage to road infrastructure	HIGH
		Influx of people causing Pressure on health and other Infrastructure	HIGH
		Increase in sexually transmitted disease and other communicable diseases	HIGH
		Reduction in air quality	HIGH
		Loss of vegetation and wildlife	HIGH
		Habitat fragmentation	HIGH
		Loss of aquatic species (Fisheries, Planktons and benthic fauna)	HIGH
		Distortion of aquatic environment (physical components)	HIGH
		Increase in noise and vibration	HIGH
		Increase in refined hydrocarbon contents of soil and vegetation	HIGH

Project phase	Project activity	Description of impact	Potential and Associated Impact (ISO 14001 method)
		Increase in crime rate	MEDIUM
		Loss of cultural/heritage sites	MEDIUM
		Contamination of groundwater	HIGH
		Soil compaction	LOW
		Increase in waste	HIGH
Construction	Wells/locations/pipelines <ul style="list-style-type: none"> • Route & location clearing • Dredging, • Pipeline river crossing, • Pilling, • Concrete and asphalt works, • Excavation • Backfilling • Pipeline coating • Stringing & welding; NDT and cathodic protection • Base camp activities 	Increase in respiratory tract infection	HIGH
		Land take	MEDIUM
		Increase in population due to influx of persons	HIGH
		Increase in social vices (Alcohol and drug abuse, CSWs)	HIGH
		Crime and insecurity (Kidnapping, Hostage-taking, armed robbery, Militancy)	HIGH
		Injury/fatality of workforce and/or third party	HIGH
		Road traffic disruption	HIGH
		Increase in volume of wastes	HIGH
		Increase in employment/business opportunities	P
		Shift from traditional occupations	HIGH
		Inflation	HIGH
		Gender imbalance	HIGH

Project phase	Project activity	Description of impact	Potential and Associated Impact (ISO 14001 method)
		Potential for skills acquisition	P
		Pressure on existing infrastructure and services (Water, Electricity, Recreational facilities, Health facilities, Roads and others)	HIGH
		Increase in communicable diseases, STIs HIV/AIDS	HIGH
		Change in topography	HIGH
		Change in hydrology (groundwater)	MEDIUM
		Surface water pollution/distortion (increase in turbidity and Total Suspended Solids)	HIGH
		Soil pollution	HIGH
		Loss of biodiversity and Distortion of food chain (Economic trees)	HIGH
		Impairment/Loss of aquatic life (Loss of juvenile fishes due to gill damage from silt particles)	HIGH
		Increase in disease vectors	HIGH
		Blockage of natural water courses	HIGH
		Increase in road traffic/ potential for accidents and injuries	HIGH
		Food insecurity	HIGH

Project phase	Project activity	Description of impact	Potential and Associated Impact (ISO 14001 method)
		Erosion	HIGH
		Loss of indigenous languages	LOW
		Loss of fish breeding sites and migratory routes	HIGH
		Noise and vibration	HIGH
		Reduction in air quality	HIGH
		Opportunity for direct and indirect Employment	P
		Opportunity for wealth creation	P
		Opportunity for Corporate Social Responsibility	P
		Exposure to radioactive materials	HIGH
		Third party agitation	HIGH
		Potential attack from wild/predatory animals (Snakes, Scorpions)	HIGH
		Increase in exposure to transborder diseases (Zika virus, Ebola, Birdflu, SARS), Antimicrobial resistant bacteria	HIGH
		Crime and insecurity (Kidnapping, Hostage-taking, armed robbery, Militancy)	HIGH
		Access to hunting grounds	MEDIUM
		Potential reduction in household water quality and contamination of potable water	HIGH

Project phase	Project activity	Description of impact	Potential and Associated Impact (ISO 14001 method)
		Temporary disruption of local fishing/harvesting activities.	MEDIUM
		Acidification of the soil and surface water as a result of deposition of dredge spoils on the banks of the river	MEDIUM
		Spoil disposal will smother epifauna and impair surface drainage especially in wetland areas	MEDIUM
		Disaggregation of benthic habitats and loss of benthic organisms.	MEDIUM
		Disturbance of riverbed topography and re-suspension of fine sediments and bottom materials	MEDIUM
		Disturbance of riverbed topography	MEDIUM
	Drilling and well hook-up	Increase in noise & vibration nuisance	HIGH
		Increase in light nuisance	HIGH
		Generation of drilling waste	HIGH
		Contamination of environment (soils/surface and groundwater)	HIGH
		Work related injury/fatality of workforce	HIGH
	Non work related injury/fatality of workforce	HIGH	

Project phase	Project activity	Description of impact	Potential and Associated Impact (ISO 14001 method)
		Increase in explosion potential (Well blowout)	HIGH
		Increase in diseases STIs, HIV/AIDS	HIGH
		Increase in endemic diseases	HIGH
		Emergent Infectious diseases resulting from displacement of disease vectors (rodents and monkeys)	HIGH
		Loss of biodiversity	HIGH
		Potential for development of infrastructures and economic enhancement	P
		Increase in road traffic volume & accident potential/injuries	HIGH
		Tank leaks	HIGH
		Influx of insect pests	HIGH
		Opportunity for direct and indirect Employment (Unskilled labour)	P
		Opportunity for wealth creation	P
		Opportunity for Corporate Social Responsibility	P
		Gender imbalance	HIGH
		Potential for skills acquisition	P
		Pressure on existing infrastructure and services (Water, Electricity,	HIGH

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Project phase	Project activity	Description of impact	Potential and Associated Impact (ISO 14001 method)
		Recreational facilities, Health facilities, Roads and others)	
		Third party agitation	HIGH
		Attack from wild/predatory animals (Snakes, Scorpions)	HIGH
		Exposure to radioactive materials	HIGH
		Crime and insecurity (Kidnapping, Hostage-taking, armed robbery, Militancy)	HIGH
	Well & pipeline testing, Hydrotesting,	Potential for explosion	HIGH
		Discharge of untreated test water into the receiving environment	MEDIUM
	Cathodic Protection,	Exposure to radioactive material	HIGH
	Commissioning & Handover	Increase in Business opportunities	P
		Gas flaring from well tests	HIGH
		Increase in noise & vibration nuisance	HIGH
		Generation of waste (Pigging waste, domestic waste, metal scraps, plastics)	HIGH
		Contamination of environment (soils/surface and groundwater)	HIGH
	Work related injury/fatality of workforce	HIGH	

Project phase	Project activity	Description of impact	Potential and Associated Impact (ISO 14001 method)
		Non work related injury/fatality of workforce	HIGH
		Increase in explosion potential	HIGH
		Increase in diseases STIs, HIV/AIDS	HIGH
		Increase in endemic diseases (Malaria, Typhoid, RTI)	HIGH
		Development of infrastructures and economic enhancement (GMoU)	P
		Increase in road traffic volume & accident potential/injuries	HIGH
		Tank leaks	HIGH
		Opportunity for direct and indirect Employment (Unskilled labour)	P
		Opportunity for wealth creation	P
		Loss of Employment (local labour) (Boom burst cycle)	HIGH
		Third party agitation	HIGH
		Attack from wild animals (Snakes, Scorpions)	HIGH
		Crime and insecurity (Kidnapping, Hostage-taking, armed robbery, Militancy)	HIGH
		Increased exposure to carcinogenic substances	HIGH
		Alcohol and drug abuse	HIGH

Project phase	Project activity	Description of impact	Potential and Associated Impact (ISO 14001 method)
Demobilization		Increase in road traffic, potential for accidents and injuries	HIGH
		Damage to road infrastructure	HIGH
		Impairment in air quality	HIGH
		Increase in noise and vibration	HIGH
		Increase in refined hydrocarbon contents of soil and vegetation	HIGH
		Increase in crime rate	HIGH
		Contamination of groundwater	HIGH
		Soil compaction	LOW
		Waste generation (Scrap metals, Woods, Food waste)	HIGH
		Opportunity for contracting	P
		Opportunity for direct and indirect Employment (Unskilled labour)	P
		Loss of Employment (local labour)	HIGH
		Third party agitation	HIGH
		Crime and insecurity (Kidnapping, Hostage-taking, armed robbery, Militancy)	HIGH
		Increase in RTIs due to dust particles	HIGH
		Social dislocation	HIGH
Increased exposure to carcinogenic substances	HIGH		

Project phase	Project activity	Description of impact	Potential and Associated Impact (ISO 14001 method)
		Alcohol and drug abuse	HIGH
Operation	Well work-over, Gas production,	Potential for environmental contamination due to gas leaks	HIGH
	Pipeline maintenance & replacement	Increase in business opportunities	P
		Increase in potential for injury/fatality of workforce & third parties	HIGH
		Revenue generation for government and SPDC	P
		Increase in potential for sabotage of facilities	HIGH
		Reduction in gas flaring	P
		Increase in diseases STIs HIV/AIDS	HIGH
		Prevalence in endemic diseases (Malaria, Typhoid, RTI)	HIGH
		Opportunity for contracting	P
		Opportunity for direct and indirect Employment (Unskilled labour)	P
		Third party agitation	HIGH
		Crime and insecurity (Kidnapping, Hostage-taking, armed robbery, Militancy) and other social vices	HIGH
		Waste generation (Scrap metals, Woods, Food waste)	HIGH

Project phase	Project activity	Description of impact	Potential and Associated Impact (ISO 14001 method)
		Increased exposure to carcinogenic substances	HIGH
		Alcohol and drug abuse	HIGH
		Contamination of surface water/Sediment	HIGH
Decommissioning and abandonment	<ul style="list-style-type: none"> • Flushing of pipelines • Vacuum drying of pipeline • Capping of pipeline • Removal of surface installations • Plugging of wells • Site restoration • Return of land to owner(s) 	Increase in potential for soil and water contamination	HIGH
		Increase in litigation potential	HIGH
		Loss of revenue for Govt. & SPDC	HIGH
		Loss of job by community surveillance team	HIGH
		Increase in usable land resource to the community	P
		Opportunity for contracting	P
		Opportunity for direct and indirect Employment (Unskilled labour)	P
		Third party agitation	HIGH
		Crime and insecurity (Kidnapping, Hostage-taking, armed robbery, Militancy) and other social vices	HIGH
		Waste generation (Scrap metals, Woods, Food waste)	HIGH
		Increased exposure to carcinogenic substances	HIGH
		Alcohol and drug abuse	HIGH

Project phase	Project activity	Description of impact	Potential and Associated Impact (ISO 14001 method)
		Prevalence of STIs HIV/AIDS	HIGH

CHAPTER SIX

MITIGATION MEASURES

6.1: Introduction

The actions and measures that SPDC intend to take to reduce (or eliminate) negative impacts and thus promote the positive impacts of the Enwhe FDP Project are presented in this chapter. The mitigation measures are aimed at reducing the impacts to As Low As Reasonably Practicable (ALARP). None significant impacts are expected to be mitigated through effective implementation of Health, Safety and Environment (HSE) plans that are in operational and the new ones that will be introduced. The mitigation measures proposed are in consonance with the following:

- Department of Petroleum Resources guidelines and standards,
- Environmental laws at national, regional and international levels,
- Best Available Technology for Sustainable Development;
- Social wellbeing and
- Concerns of stakeholders.

6.2: Mitigation Measures for the Cumulative impacts/effects

The proposed mitigation measures for the cumulative impacts/effects are presented in Table 6.1.

Table 6.1: Mitigation Measures for the Cumulative impacts/effects in the Enwhe FDP

Project phase	Project activity	Description of impact	Identified potential Impact	Mitigation measures	Rating After Mitigation
Pre-mobilization	<ul style="list-style-type: none"> • Consultation, • Land acquisition and • Compensation, Resolution of legacy issues 	Increase in project awareness	HIGH	<ul style="list-style-type: none"> • SPDC shall ensure adequate consultation with all stakeholders especially communities. • SPDC shall carry out sound community sensing to evaluate existing relationship between SPDC & fence line communities, collate legacy projects & agree with community on ways of addressing them to change the perception to positive. 	LOW
		Anticipated Loss of land associated resources	HIGH	<ul style="list-style-type: none"> • Land take shall be limited to the minimum required. • SPDC shall ensure consultation is done with the right responsible persons. 	LOW
		Financial enhancement	POSITIVE	<ul style="list-style-type: none"> • N/A 	LOW
		Third party agitation	HIGH	<ul style="list-style-type: none"> • Relevant stakeholders/legacy issues shall be identified. • Regular consultation with stakeholders (Govt., Community, NGOs, CBOs etc.) shall be carried out to understand community perceptions, issues and concerns • Effective liaison/communication channels (CICs) from the communities to the project execution team shall be established. • Project Advisory Committee (PAC) to guide MoU implementation shall be set up 	LOW
Mobilization	<ul style="list-style-type: none"> • Movement of equipment and personnel, • Rig movement 	Loss of livelihood	HIGH	<ul style="list-style-type: none"> • Alternative income generating activities through skills acquisition that will empower communities shall be supported. • SPDC shall encourage skills acquisition and training programmes 	LOW
		Increase in road traffic, potential for accidents and injuries	HIGH	<ul style="list-style-type: none"> ▪ Visible warning signs shall be placed at strategic positions along the roads ▪ SPDC shall ensure there is traffic control at strategic points along the road ▪ SPDC shall ensure all vehicles observe the speed limits and large vehicles have warning lights to alert other road users ▪ SPDC shall ensure all project vehicles are pre-mobbed and certified. ▪ Reverse alarm shall be installed in all Operational vehicles ▪ Speed control facilities such as IVMS and Strata shall be installed in all vehicle ▪ The 12 Life Saving Rules (LSR) shall be enforced on all road users. ▪ Effective journey Management system 	LOW

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Project phase	Project activity	Description of impact	Identified potential Impact	Mitigation measures	Rating After Mitigation
				<ul style="list-style-type: none"> ▪ Proper Risk Assessment (using JHA and Toolbox meeting) before work begins 	
		Damage to road infrastructure	HIGH	<ul style="list-style-type: none"> ▪ SPDC shall construct roads to its location where they do not exist and maintain existing roads to its location without refusing the general public from using same. 	LOW
		Influx of people causing Pressure on health and other Infrastructure	HIGH	<ul style="list-style-type: none"> ▪ SPDC shall advise the contractor to locate recruitment office away from the work site to reduce job seekers at the site. ▪ Workers camps shall be provided for the workforce by the Contractor to reduce the pressure on housing. ▪ SPDC shall ensure access control is implemented at work site ▪ Patronage of commercial sex workers by workforce shall be discouraged through health awareness campaigns to be conducted by SPDC. ▪ SPDC shall ensure unskilled and where feasible semi-skilled workers are sourced from immediate communities. ▪ SPDC shall honour all GMoU agreements ▪ SPDC and contractor shall provide for health care needs of workforce outside of those in the community. ▪ SPDC shall avoid the use of the communities' welfare facilities such as water, and Health facilities. 	LOW
		Increase in sexually transmitted disease and other communicable diseases	HIGH	<ul style="list-style-type: none"> ▪ Workers shall be encouraged to undergo voluntary counselling and testing in order to know their HIV status and in turn guide behaviour ▪ SPDC shall enforce access control to base camps. ▪ SPDC shall enforce Alcohol and drug policy in the camps / worksite as part of culture of health. 	LOW
		Reduction in air quality	HIGH	<ul style="list-style-type: none"> • SPDC shall ensure the use of sprinklers with high pressure water guns to minimize dust. • Health advise to the communities members (particularly the under aged) to stay away from construction site • Access control to the project area should enforced. 	LOW
		Loss of vegetation and wildlife	HIGH	<ul style="list-style-type: none"> • SPDC shall restrict project activities to within agreed scope and establish bond walls / fencing to avoid encroachment into unplanned zones. • Any vegetation cleared in the lay-down area shall be re-planted with native species. 	LOW

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Project phase	Project activity	Description of impact	Identified potential Impact	Mitigation measures	Rating After Mitigation
		Habitat fragmentation	HIGH	<ul style="list-style-type: none"> Clearing should be limited to areas of operation. Wildlife reserves and sacred forests shall be identified and avoided. Re-vegetation shall be undertaken after the project work where desirable. 	LOW
		Loss of aquatic species (Fisheries, Planktons and benthic fauna)	HIGH	<ul style="list-style-type: none"> SPDC shall establish skill acquisition / training scheme. SPDC shall implement Biodiversity Action Plan of the Gbaran Ubie IOGP. Research and development shall be encouraged to prevent habitat alteration to the barest minimum. 	LOW
		Distortion of aquatic environment (physical components)	HIGH	<ul style="list-style-type: none"> SPDC shall establish skill acquisition / training scheme. SPDC shall implement Biodiversity Action Plan of the Gbaran Ubie IOGP. Research and development shall be encouraged to prevent habitat alteration to the barest minimum. 	LOW
		Increase in noise and vibration	HIGH	<ul style="list-style-type: none"> Mufflers shall be installed on machineries and low noise generators shall be used. Noise level shall be monitored to ensure safe levels are not exceeded. There shall be no night work 	LOW
		Increase in refined hydrocarbon contents of soil and vegetation	HIGH	<ul style="list-style-type: none"> SPDC shall ensure fuel bunkering is done within stipulated bonded area that is leak proof to avoid contamination. SPDC shall encourage regular servicing of vehicles to reduce emissions from exhaust. Vehicles should fuel and refuel at designated stations. 	LOW
		Increase in crime rate	HIGH	<ul style="list-style-type: none"> SPDC shall advise the contractor to site recruitment office away from the work site to reduce job seekers at the site. SPDC shall ensure access control is implemented at work site SPDC shall implement proper journey management system. SPDC shall work with the Government, communities and other relevant agencies to improve security in the project area SPDC shall ensure that security orientation and awareness is conducted for workforce. SPDC shall ensure that security orientation and awareness is conducted for workforce. 	MEDIUM

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Project phase	Project activity	Description of impact	Identified potential Impact	Mitigation measures	Rating After Mitigation
		Loss of cultural/heritage sites	High	<ul style="list-style-type: none"> Historical sites/sacred places, fishing sites/grounds and other areas of interest to the communities shall be avoided during land acquisition. Designate authentic shrines as protected cultural properties 	LOW
		Soil compaction	LOW	<ul style="list-style-type: none"> SPDC shall ensure that there is restriction to permanent wheel tracks. SPDC shall ensure trucks avoid waterlogged routes. 	LOW
		Increase in waste	HIGH	<ul style="list-style-type: none"> SPDC and contractors shall ensure that all wastes are segregated and managed according to EGASPIN/FMEnv. Ensure proper documentation of the quantity of waste from generated site to disposal point 	LOW
Construction	Wells/locations/pipelines <ul style="list-style-type: none"> Route & location clearing Dredging, Pipeline river crossing, Pilling, Concrete and asphalt works, Excavation Backfilling Pipeline coating Stringing & welding; NDT and cathodic protection Base camp activities 	Increase in respiratory tract infection	HIGH	<ul style="list-style-type: none"> SPDC shall wet the site before excavation and construction to minimize dust. Health advise to the communities members (particularly the under aged) to stay away from construction site Access control to the project area should enforced 	LOW
		Land take	MEDIUM	<ul style="list-style-type: none"> Land take shall be limited to the minimum required. SPDC shall ensure consultation is done with the right responsible persons 	LOW
		Increase in population due to influx of persons	HIGH	<ul style="list-style-type: none"> SPDC shall advise the contractor to site recruitment office away from the work site to reduce job seekers at the site. SPDC shall ensure access control is implemented at work site SPDC shall ensure health awareness campaigns are conducted for workforce on the risks of STIs from the services of CSWs to discourage patronage SPDC shall ensure unskilled and where feasible semi-skilled workers are sourced from immediate communities SPDC shall support existing health facilities upgrade and staff training. SPDC will house workers in camps to reduce pressure and local housing stock. SPDC shall comply with local content policy. 	LOW
		Increase in social vices (Alcohol and drug abuse, CSWs)	HIGH	<ul style="list-style-type: none"> Ensure the implementation of the company's alcohol and drug policies Pre-activity health/sex education campaign shall be conducted for both workforce and communities. 	LOW

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Project phase	Project activity	Description of impact	Identified potential Impact	Mitigation measures	Rating After Mitigation
		Crime and insecurity (Kidnapping, Hostage-taking, armed robbery, Militancy)	HIGH	<ul style="list-style-type: none"> SPDC shall advise the contractor to site recruitment office away from the work site to reduce job seekers at the site. SPDC shall ensure access control is implemented at work site SPDC shall implement proper journey management system. SPDC shall work with the Government, communities and other relevant agencies to improve security in the project area SPDC shall ensure that security orientation and awareness is conducted for workforce. SPDC shall ensure that security orientation and awareness is conducted for workforce. 	MEDIUM
		Injury/fatality of workforce and/or third party	HIGH	<ul style="list-style-type: none"> SPDC shall enforce the use of appropriate PPEs (life jackets, work vests/ goggles etc). SPDC shall ensure first aid box on site and emergency response and med-rescue/medevac are in place. Toolbox meetings shall be held before the start of daily tasks Awareness shall be created among site workers on the likelihood of exposure to poisonous wildlife & plants. Trained First Aiders shall form part of the workforce SPDC policy on road traffic journey management shall be adhered to (all journey must be approved, no night journeys, speed limits on land) 	LOW
		Road traffic disruption	HIGH	SPDC shall upgrade existing roads to suite the anticipated project activities and additional access road provided, where necessary	LOW
		Increase in volume of wastes	HIGH	<ul style="list-style-type: none"> SPDC and contractors shall ensure that all wastes are segregated and managed according to EGASPIN/FMEnv guidelines. Ensure proper documentation of the quantity of waste from generated site to disposal point 	LOW
		Increase in employment/business opportunities	POSITIVE	NA	POSITIVE
		Shift from traditional occupations	HIGH	<ul style="list-style-type: none"> SPDC shall discuss and agree on sustainable community development project and implement agreed projects. 	LOW
		Inflation	HIGH	<ul style="list-style-type: none"> Alternative income generating activities through skills acquisition that will empower communities 	LOW

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Project phase	Project activity	Description of impact	Identified potential Impact	Mitigation measures	Rating After Mitigation
				shall be introduced and supported by SPDC and Contactors. <ul style="list-style-type: none"> SPDC and Contractors shall provide accommodation for operational staff at the base camps and provide catering services. 	
		Gender imbalance	HIGH	<ul style="list-style-type: none"> SPDC shall enforce existing laws against gender-based employment discrimination and against sexual harassment. SPDC shall Increase mentorship and other efforts to boost the number of women in traditionally male occupations. 	LOW
		Potential for skills acquisition	P	NA	POSITIVE
		Pressure on existing infrastructure and services (Water, Electricity, Recreational facilities, Health facilities, Roads and others)	HIGH	<ul style="list-style-type: none"> SPDC shall advise the contractor to locate recruitment office away from the work site to reduce job seekers at the site Workers camps shall be provided for the workforce by the Contractor to reduce the pressure on housing. SPDC shall ensure access control is implemented at work site Patronage of commercial sex workers by workforce shall be discouraged through health awareness campaigns to be conducted by SPDC. SPDC shall ensure unskilled and where feasible semi-skilled workers are sourced from immediate communities. SPDC shall honour all GMOU agreements SPDC and contractor shall provide for health care needs of workforce outside of those in the community. Construction should be done in phases so as to reduce the number of workers at site in any particular time Health education on communicable disease transmissions. 	LOW
		Increase in communicable diseases, STIs HIV/AIDS	HIGH	<ul style="list-style-type: none"> Workers shall be encouraged to undergo voluntary counselling and testing in order to know their HIV status and in turn guide behaviour SPDC shall enforce access control to base camps SPDC shall enforce Alcohol and drug policy in the camps /worksites as part of culture of health. 	LOW
		Change in topography	HIGH	<ul style="list-style-type: none"> Trenching shall be limited to the minimum size required and excavated sand managed properly. Fill material for sand filling shall be sourced from BYSMENV approved sites 	LOW

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Project phase	Project activity	Description of impact	Identified potential Impact	Mitigation measures	Rating After Mitigation
		Surface water pollution/distortion (increase in turbidity and Total Suspended Solids)	HIGH	SPDC shall deploy the most appropriate technology (silt curtain), to minimize loss of benthic organisms.	LOW
		Soil pollution	HIGH	<ul style="list-style-type: none"> Wastes shall be segregated at source into color-coded or labelled bins and disposed of in line with a project specific waste management plan. Safe Handling of Chemicals (SHOC) cards shall be visibly displayed at all sites where chemicals are handled Fuel, lube oils and chemicals shall be safely stored in containers in bunded areas 	LOW
		Loss of biodiversity and Distortion of food chain (Economic trees)	HIGH	<ul style="list-style-type: none"> Any vegetation cleared in the lay-down area shall be re-planted with native species. SPDC shall ensure awareness campaigns are conducted for the workforce on the need to preserve the environment. Route clearing shall be done in stages to allow mobile fauna escape from the project area. 	LOW
		Impairment/Loss of aquatic life (Loss of juvenile fishes due to gill damage from silt particles)	HIGH	SPDC shall deploy the most appropriate technology (silt curtain), to minimize loss of benthic organisms and fishery resources.	LOW
		Increase in disease vectors	HIGH	<ul style="list-style-type: none"> SPDC shall assist the communities in pest control measures Health education on the Health Implication of Rodents/other disease vectors in their homes. SPDC shall ensure that waste generated from the project during the period of construction are managed from cradle to grave. Health education on the consumption of rodents shall be provided by appropriate health authorities 	LOW
		Blockage of natural water courses	HIGH	SPDC shall ensure that no natural water course is unduly obstructed /blocked during the implementation of the project, equalization culverts shall be installed where necessary.	LOW
		Increase in road traffic/ potential for accidents and injuries	HIGH	<ul style="list-style-type: none"> Road safety awareness campaigns for both workers and the community. Medical facilities shall be provided on-site with critical cases transferred to retainer clinics in Yenagoa or Port Harcourt. SPDC shall ensure Med-rescue/medevac services are adequate and in place. Visible warning signs shall be placed at strategic positions along the roads. SPDC shall ensure there is traffic control at strategic points along the road. 	LOW

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Project phase	Project activity	Description of impact	Identified potential Impact	Mitigation measures	Rating After Mitigation
				<ul style="list-style-type: none"> SPDC shall ensure all vehicles observe the speed limits and large vehicles have warning lights to alert other road users. SPDC shall ensure all project vehicles are pre-mobbed and certified 	
		Food insecurity	HIGH	<ul style="list-style-type: none"> Livewire Program shall be introduced for the youths in the communities 	LOW
		Erosion	HIGH	SPDC shall ensure that no natural water course is unduly obstructed/blocked during the implementation of the project, equalization culverts shall be installed.	LOW
		Loss of fish breeding sites and migratory routes	HIGH	<ul style="list-style-type: none"> SPDC shall reduce vegetation clearing to the minimum. SPDC shall implement the Biodiversity Action Plan SPDC shall optimize the existing pipelines RoW and roads. 	LOW
		Noise and vibration	HIGH	<ul style="list-style-type: none"> Mufflers shall be installed on machineries and low noise generators shall be used. Noise level shall be monitored to ensure safe levels are not exceeded. There shall be no night work 	LOW
		Reduction in air quality	HIGH	<ul style="list-style-type: none"> SPDC shall wet the site before excavation and construction to minimize dust. Health advise to the communities members (particularly the under aged) to stay away from construction site Access control to the project area shall be enforced. 	LOW
		Opportunity for direct and indirect Employment	POSITIVE	NA	POSITIVE
		Opportunity for wealth creation	POSITIVE	NA	POSITIVE
		Opportunity for Corporate Social Responsibility	POSITIVE	NA	POSITIVE
		Exposure to radioactive materials	HIGH	<ul style="list-style-type: none"> SPDC shall ensure that only certified personnel handle radioactive materials. SPDC shall ensure that radioactive materials are stored safely. SPDC shall ensure toolbox talks are conducted before the commencement of the job. SPDC shall ensure appropriate PPEs are used by the workers 	LOW
		Third party agitation	HIGH	<ul style="list-style-type: none"> SPDC shall enlighten its contractors and project personnel prior to deployment on proper conduct within stakeholder communities 	LOW

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Project phase	Project activity	Description of impact	Identified potential Impact	Mitigation measures	Rating After Mitigation
				<ul style="list-style-type: none"> SPDC shall maintain effective liaison/communication with communities and ensure the community cultural profile is not infringed. 	
		Potential attack from wild/predatory animals (Snakes, Scorpions)	HIGH	SPDC shall <ul style="list-style-type: none"> SPDC shall ensure that waste generated from the project during the period of construction are managed from cradle to grave. The site clinic shall stock anti-snake bite venom Awareness shall be created among workers on the possibility of exposure to poisonous wildlife Ensure adequate Medivac system and on site referral system. 	LOW
		Increase in exposure to transborder diseases (Zika virus, Ebola, Birdflu, SARS), Antimicrobial resistant bacteria	HIGH	<ul style="list-style-type: none"> SPDC shall ensure that Expatriate staff pass through proper immigration Health checks before arriving at the worksite. SPDC shall ensure Health education is part of orientation for all foreign staff. Fitness-to-Work protocol must be adhered strictly to and Implemented by site supervisors and OHNs. 	LOW
		Crime and insecurity (Kidnapping, Hostage-taking, armed robbery, Militancy)	HIGH	SPDC shall <ul style="list-style-type: none"> advise the contractors to site recruitment office away from the work site to reduce job seekers at the site SPDC shall ensure access control is implemented at work site. SPDC shall implement proper journey management system. Work with the Government, communities and other relevant agencies to improve security in the project area. ensure that security orientation and awareness is conducted for workforce. Work with the Government, communities and other relevant agencies to improve security in the project area ensure that security orientation and awareness is conducted for workforce. 	LOW
		Access to hunting grounds	MEDIUM	Establishment of agricultural extension services and empowerment scheme.	LOW
		Potential reduction in household water quality and contamination of potable water	HIGH	<ul style="list-style-type: none"> SPDC shall provide water for their staff in the camps during construction and operations. Large proportion of the semi-skilled and un-skilled labours shall be sourced from the communities to reduce migrant workers. 	LOW

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Project phase	Project activity	Description of impact	Identified potential Impact	Mitigation measures	Rating After Mitigation
				<ul style="list-style-type: none"> Staff recruitment shall be done outside the communities for skilled labours not excluding the members of the communities. 	
		Temporary disruption of local fishing/harvesting activities.	MEDIUM	SPDC shall ensure strict compliance with good marine journey management practice, including sensitization of quarter masters / boat masters on how to pass fishing and commercial boat	LOW
		Acidification of the soil and surface water as a result of deposition of dredge spoils on the banks of the river	MEDIUM	SPDC shall ensure dredge spoil is deposited at least 10 metres into the buffer zone or Cap spoil with clean sand.	LOW
		Spoil disposal will smother epifauna and impair surface drainage especially in wetland areas	MEDIUM	SPDC shall dispose dredge spoils in an environmentally-friendly manner	LOW
		Disaggregation of benthic habitats and loss of benthic organisms.	MEDIUM	SPDC shall adopt due diligence to minimize adverse impacts on benthic organisms	LOW
		Disturbance of riverbed topography and re-suspension of fine sediments and bottom materials	MEDIUM	SPDC shall ensure minimal disturbance to the river bed during pipeline crossing.	LOW
		Disturbance of riverbed topography	MEDIUM	SPDC shall ensure minimal disturbance to the river bed during pipeline crossing.	LOW
	Drilling and well hook-up	Increase in noise & vibration nuisance	HIGH	<ul style="list-style-type: none"> SPDC shall provide PPEs (ear muffs, eye goggles) for drilling staff. Where possible SPDC shall provide acoustic enclosure for noisy equipment. First Aid boxes shall be provided at the drilling site and trained First Aiders remain part of the workforce. 	LOW
		Increase in light nuisance	HIGH	<ul style="list-style-type: none"> Construction activities requiring continuous light at night shall be reduced to the barest minimum. Construction activities shall be completed on schedule 	LOW
		Generation of drilling waste	HIGH	<ul style="list-style-type: none"> SPDC shall ensure that high G-shakers are used to reduce the amount of mud in drill cuttings. Recovered drilling mud shall be stored in containers for re-use. Where feasible cuttings re-injection shall be utilized 	LOW
		Contamination of environment (soils/surface and groundwater)	HIGH	<ul style="list-style-type: none"> All generated wastes shall be managed in accordance with the provisions of the SPDC Waste Management Guidelines. Where contamination occurs SPDC shall clean up and remediate as appropriate. 	LOW

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Project phase	Project activity	Description of impact	Identified potential Impact	Mitigation measures	Rating After Mitigation
		Work related injury/fatality of workforce	HIGH	<ul style="list-style-type: none"> Workers shall use appropriate PPEs (life jackets, work vests/ goggles etc) SPDC shall ensure first aid box on site and emergency response and med-rescue/medevac are in place. Toolbox meetings shall be held before the start of daily tasks Awareness shall be created among site workers on the likelihood of exposure to poisonous wildlife & plants. Trained First Aiders shall form part of the workforce. SPDC policy on road and water borne traffic journey management shall be adhered to (all journey must be approved, no night journeys, speed limits on land and water. 	LOW
		Non work related injury/fatality of workforce	HIGH	<ul style="list-style-type: none"> SPDC shall ensure all the workers at site have a medical fitness to work and are in good physical and mental health. SPDC policy on road and water borne traffic journey management shall be adhered to (all journey must be approved, no night journeys, speed limits on land and water. 	LOW
		Increase in explosion potential (Well blowout)	HIGH	<ul style="list-style-type: none"> Firefighting extinguishers shall be provided at worksites. Emergency response procedures shall be put in place. SPDC shall use the optiwell (bore hole management) process & other industry best practice to drill wells. 	LOW
		Increase in diseases STIs, HIV/AIDS	HIGH	<ul style="list-style-type: none"> Workers shall be encouraged to undergo voluntary counselling and testing in order to know their HIV status and in turn guide behaviour SPDC shall ensure condoms are provided for workers at the site clinic and distributed to the communities SPDC shall enforce access control to base camps SPDC shall enforce Alcohol and drug policy in the camps /worksite as part of culture of health. 	LOW
		Increase in endemic diseases	HIGH	<ul style="list-style-type: none"> SPDC shall support existing health facilities upgrade and staff training. SPDC shall maintain workers in camp and provide access control measure to reduce intermingling with host communities. 	LOW

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Project phase	Project activity	Description of impact	Identified potential Impact	Mitigation measures	Rating After Mitigation
		Emergent Infectious diseases resulting from displacement of disease vectors (rodents and monkeys)	HIGH	<ul style="list-style-type: none"> ▪ SPDC shall ensure that waste generated from the project during the period of construction are managed from cradle to grave. ▪ Health education on the consumption of rodents shall be provided by appropriate health authorities. 	LOW
		Loss of biodiversity	HIGH	<ul style="list-style-type: none"> ▪ Any vegetation cleared in the lay-down area shall be re-planted with native species. ▪ SPDC shall ensure that her workforce do not engage in hunting or fishing. ▪ SPDC shall ensure awareness campaigns are conducted for the workforce on the need to preserve the environment. ▪ Route clearing shall be done in stages to allow mobile fauna escape from the project area. ▪ SPDC shall implement the BAP policy. 	LOW
		Potential for development of infrastructures and economic enhancement	P	NA	POSITIVE
		Increase in road traffic volume & accident potential/injuries	HIGH	<ul style="list-style-type: none"> • SPDC policy on road and water borne traffic journey management shall be adhered to (all journey must be approved, no night journeys, speed limits on land and water • SPDC shall upgrade existing roads to suite the anticipated project activities and additional access road provided, where necessary 	LOW
		Tank leaks	HIGH	<ul style="list-style-type: none"> • All Liquid containers shall be placed in leak-proof bonded concrete housing with proper ventilation. • SPDC shall ensure only certified personnel are allowed to carry-out fuel bunkering / transfer. • The storage shall be properly marked and condoned off from the general worksite public. 	LOW
		Influx of insect pests	HIGH	<ul style="list-style-type: none"> ▪ SPDC shall carryout health education programmes on the Rollback Malaria interventions. ▪ Ensure adequate referral system 	LOW
		Opportunity for direct and indirect Employment (Unskilled labour)	P	NA	POSITIVE
		Opportunity for wealth creation	P	NA	POSITIVE
		Opportunity for Corporate Social Responsibility	P	NA	POSITIVE
		Gender imbalance	HIGH	<ul style="list-style-type: none"> • SPDC shall enforce existing laws against gender-based employment discrimination and against sexual harassment. 	LOW

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Project phase	Project activity	Description of impact	Identified potential Impact	Mitigation measures	Rating After Mitigation
				<ul style="list-style-type: none"> SPDC shall Increase mentorship and other efforts to boost the number of women in traditionally male occupations. 	
		Potential for skills acquisition	P	NA	P
		Pressure on existing infrastructure and services (Water, Electricity, Recreational facilities, Health facilities, Roads and others)	HIGH	<ul style="list-style-type: none"> SPDC shall advise the contractor to locate recruitment office away from the work site to reduce job seekers at the site Workers camps shall be provided for the workforce by the Contractor to reduce the pressure on housing. SPDC shall ensure access control is implemented at work site Patronage of commercial sex workers by workforce shall be discouraged through health awareness campaigns to be conducted by SPDC. SPDC shall ensure unskilled and where feasible semi-skilled workers are sourced from immediate communities. SPDC and contractor shall provide for health care needs of workforce outside of those in the community. Construction should be done in phases so as to reduce the number of workers at site in any particular time. 	LOW
		Third party agitation	HIGH	<ul style="list-style-type: none"> SPDC shall implement the PGMOU in line with agreed template. SPDC shall enlighten its contractors and project personnel prior to deployment on proper conduct within stakeholder communities and maintain effective liaison/communication with communities and ensure the community's economic and cultural profiles are not infringed. 	LOW
		Attack from wild/predatory animals (Snakes, Scorpions)	HIGH	<ul style="list-style-type: none"> SPDC shall ensure that waste generated from the project during the period of construction are managed from cradle to grave. The site clinic shall stock anti-snake bite venom Awareness shall be created among workers on the possibility of exposure to poisonous wildlife Ensure adequate Medivac system and on site referral system. 	LOW
		Exposure to radioactive materials	HIGH	<ul style="list-style-type: none"> SPDC shall ensure that only certified personnel handle radioactive materials. SPDC shall ensure that radioactive materials are stored safely. 	LOW

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Project phase	Project activity	Description of impact	Identified potential Impact	Mitigation measures	Rating After Mitigation
				<ul style="list-style-type: none"> ▪ SPDC shall ensure toolbox talks are conducted before the commencement of the job ▪ SPDC shall ensure appropriate PPEs are used by the workers 	
		Crime and insecurity (Kidnapping, Hostage-taking, armed robbery, Militancy)	HIGH	<ul style="list-style-type: none"> • SPDC shall advise the contractor to site recruitment office away from the work site to reduce job seekers at the site. • SPDC shall ensure access control is implemented at work site • SPDC shall implement proper journey management system. • SPDC shall work with the Government, communities and other relevant agencies to improve security in the project area • SPDC shall ensure that security orientation and awareness is conducted for workforce. • SPDC shall ensure that security orientation and awareness is conducted for workforce. 	MEDIUM
	Well & pipeline testing, Hydrotesting,	Potential for explosion	HIGH	<ul style="list-style-type: none"> • Firefighting extinguishers shall be provided at worksites. • Emergency response procedures shall be put in place 	LOW
		Discharge of untreated test water into the receiving environment	MEDIUM	SPDC waste management specifications and guidelines (especially with regards to the discharges into the environment) shall be complied with.	LOW
	Cathodic Protection,	Exposure to radioactive material	HIGH	<ul style="list-style-type: none"> • SPDC shall ensure that only certified personnel handle radioactive materials. • SPDC shall ensure that radioactive materials are stored safely. • SPDC shall ensure toolbox talks are conducted before the commencement of the job. • SPDC shall ensure appropriate PPEs are used by the workers 	LOW
	Commissioning & Handover	Increase in Business opportunities	P	NA	POSITIVE
		Gas flaring from well tests	HIGH	<p>SPDC shall ensure</p> <ul style="list-style-type: none"> • Safety signage shall be deployed at strategic locations. • Emergency response plan shall be in place • Use of appropriate PPEs • provision of adequate firefighting equipment 	LOW
		Increase in noise & vibration nuisance	HIGH	<ul style="list-style-type: none"> ▪ Mufflers shall be installed on machineries and low noise generators shall be used. 	LOW

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Project phase	Project activity	Description of impact	Identified potential Impact	Mitigation measures	Rating After Mitigation
				<ul style="list-style-type: none"> ▪ Noise level shall be monitored to ensure safe levels are not exceeded. ▪ There shall be no night work ▪ Noise in the communities shall be measured every three months 	
		Generation of waste (Pigging waste, domestic waste, metal scraps, plastics)	HIGH	<ul style="list-style-type: none"> ▪ SPDC and contractors shall ensure that all wastes are segregated and managed according to EGASPIN and FMEV guidelines. ▪ Enforce access control to ensure that wastes are not indiscriminately transferred from one place to the other by members of the communities in the act of picking properties. ▪ Ensure proper documentation of the quantity of waste from generated site to disposal point 	LOW
		Contamination of environment (soils/surface and groundwater)	HIGH	<ul style="list-style-type: none"> • Waste management plans (in line with regulatory guidelines and SPDC procedures) shall be strictly adhered to during all phases of the project. • Wastes shall be segregated at source into color-coded or labelled bins and disposed of in line with a project specific waste management plan. • SPDC shall ensure that sewage wastes in base camps are properly managed. • Safe Handling of Chemicals (SHOC) cards shall be visibly displayed at all sites where chemicals are handled • Fuel, lube oils and chemicals shall be safely stored in containers in bonded areas 	LOW
		Work related injury/fatality of workforce	HIGH	<ul style="list-style-type: none"> ▪ Workers shall use appropriate PPEs (life jackets, work vests/ goggles etc) ▪ SPDC shall ensure first aid box on site and emergency response and medevac are in place ▪ Toolbox meetings shall be held before the start of daily tasks ▪ Awareness shall be created among site workers on the likelihood of exposure to poisonous wildlife & plants ▪ Trained First Aiders shall form part of the workforce in the ratio of 1:25 ▪ Ensure adequate MEDEVAC and referral system 	LOW
		Non work related injury/fatality of workforce	HIGH	<ul style="list-style-type: none"> • SPDC shall ensure every worker have a medical certificate of fitness to work. • SPDC shall ensure that workers suffering from terminal diseases are not accommodate in camp. 	LOW

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				<ul style="list-style-type: none"> SPDC shall ensure that a trained medic is assigned to the site camp. 	
		Increase in explosion potential	HIGH	<ul style="list-style-type: none"> Firefighting extinguishers shall be provided at worksites Emergency response procedures shall be put in place. SPDC shall use the optiwell (bore hole management) process & other industry best practice to drill her wells 	LOW
		Increase in diseases STIs, HIV/AIDS	HIGH	<ul style="list-style-type: none"> Workers shall be encouraged to undergo voluntary counselling and testing in order to know their HIV status and in turn guide behaviour SPDC shall enforce access control to base camps SPDC shall enforce Alcohol and drug policy in the camps /worksite as part of culture of health. 	LOW
		Increase in endemic diseases (Malaria, Typhoid, RTI)	HIGH	<ul style="list-style-type: none"> Carryout health education on the Rollback Malaria interventions. Ensure adequate referral system 	LOW
		Development of infrastructures and economic enhancement (GMOU)	P	NA	POSITIVE
		Increase in road traffic volume & accident potential/injuries	HIGH	<ul style="list-style-type: none"> SPDC shall ensure all vehicles are pre-mobbed and certified. Visible warning signs shall be placed on roads and vehicle. SPDC shall ensure all drivers undergo the defensive driving course and are certified. Vehicle monitoring and communication devices shall be installed in project vehicles. SPDC shall ensure journey management and 'no night driving policy' shall be adhered to. SPDC shall ensure compulsory medical fitness test for all drivers 	LOW
		Tank leaks	HIGH	<ul style="list-style-type: none"> All Liquid containers shall be placed in leak-proof bonded concrete housing with proper ventilation. SPDC shall ensure only certified personnel are allowed to carry-out fuel bunkering / transfer. The storage shall be properly marked and condoned off from the general worksite public. 	LOW
		Opportunity for direct and indirect Employment (Unskilled labour)	P	NA	POSITIVE
		Opportunity for wealth creation	P	NA	POSITIVE

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Project phase	Project activity	Description of impact	Identified potential Impact	Mitigation measures	Rating After Mitigation
		Loss of Employment (local labour) (Boom burst cycle)	HIGH	SPDC shall as long as reasonably possible ensure the engagement of community members when actual production begins	LOW
		Third party agitation	HIGH	<ul style="list-style-type: none"> SPDC shall implement the GMoU in line with agreed template. SPDC shall enlighten its contractors and project personnel prior to deployment on proper conduct within stakeholder communities and maintain effective liaison/communication with communities and ensure the community's economic and cultural profiles are not infringed. 	LOW
		Attack from wild animals (Snakes, Scorpions)	HIGH	<ul style="list-style-type: none"> SPDC shall ensure that waste generated from the project during the period of construction are managed from cradle to grave. Health education on the consumption of rodents shall be provided by appropriate health authorities The site clinic shall stock anti-snake bite venom Awareness shall be created among workers on the possibility of exposure to poisonous wildlife Ensure adequate Medivac system and on site referral system. 	LOW
		Crime and insecurity (Kidnapping, Hostage-taking, armed robbery, Militancy)	HIGH	<ul style="list-style-type: none"> SPDC shall advise the contractor to site recruitment office away from the work site to reduce job seekers at the site. SPDC shall ensure access control is implemented at work site SPDC shall implement proper journey management system. SPDC shall work with the Government, communities and other relevant agencies to improve security in the project area SPDC shall ensure that security orientation and awareness is conducted for workforce. SPDC shall ensure that security orientation and awareness is conducted for workforce. 	MEDIUM
		Increased exposure to carcinogenic substances	HIGH	<ul style="list-style-type: none"> SPDC shall carryout awareness campaign in educating the communities members to keep the required distance when rays are being used for welding joints and other radioactive services. SPDC shall ensure that the emergency contingencies are in place to address any spill to minimise contamination of food and water sources. 	LOW
		Alcohol and drug abuse	HIGH	<ul style="list-style-type: none"> Ensure the implementation of the company's alcohol and drug policies 	LOW

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Project phase	Project activity	Description of impact	Identified potential Impact	Mitigation measures	Rating After Mitigation	
				<ul style="list-style-type: none"> ▪ Pre-activity health/sex education campaign shall be conducted for both workforce and communities. 		
Demobilization		Increase in road traffic, potential for accidents and injuries	HIGH	<ul style="list-style-type: none"> • Visible warning signs shall be placed at strategic positions along the roads. • SPDC shall ensure there is traffic control at strategic points along the road. • SPDC shall ensure all vehicles observe the speed limits and large vehicles have warning lights to alert other road users. • SPDC shall ensure all project vehicles are pre-mobbed and certified 	LOW	
		Damage to road infrastructure	HIGH	SPDC shall built roads to its location where they do not exist and maintain existing roads to its location without refusing the general public from using same.	LOW	
		Impairment in air quality	HIGH	<ul style="list-style-type: none"> • SPDC shall wet the site before excavation and construction to minimize dust. • Access control to the project area should enforced • Health education shall be delivered to the communities members on the need to dependence on the use of firewood due to negative health effect. 	LOW	
			Increase in noise and vibration	HIGH	<ul style="list-style-type: none"> ▪ Mufflers shall be installed on machineries and low noise generators shall be used. ▪ Noise level shall be monitored to ensure safe levels are not exceeded. ▪ There shall be no night work 	LOW
			Increase in refined hydrocarbon contents of soil and vegetation	HIGH	<ul style="list-style-type: none"> • SPDC shall ensure fuel bunkering is done within stipulated bonded area that is leak proof to avoid contamination. • Service vehicles regularly to reduce emissions from exhaust. • Vehicles should fuel and refuel at designated stations. 	LOW
			Increase in crime rate	HIGH	<ul style="list-style-type: none"> • SPDC shall advise the contractor to site recruitment office away from the work site to reduce job seekers at the site. • SPDC shall ensure access control is implemented at work site • SPDC shall implement proper journey management system. • SPDC shall work with the Government, communities and other relevant agencies to improve security in the project area • SPDC shall ensure that security orientation and awareness is conducted for workforce. 	MEDIUM

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Project phase	Project activity	Description of impact	Identified potential Impact	Mitigation measures	Rating After Mitigation
				<ul style="list-style-type: none"> SPDC shall ensure that security orientation and awareness is conducted for workforce. 	
		Soil compaction	LOW	<ul style="list-style-type: none"> SPDC shall ensure that there is restriction to permanent wheel tracks. SPDC shall ensure trucks avoid waterlogged routes. 	LOW
		Waste generation (Scrap metals, Woods, Food waste)	HIGH	<ul style="list-style-type: none"> Waste management plans (in line with regulatory guidelines and SPDC procedures) shall be strictly adhered to during all phases of the project. Wastes shall be segregated at source into color-coded or labelled bins and disposed of in line with a project specific waste management plan 	LOW
		Opportunity for contracting	P	NA	POSITIVE
		Opportunity for direct and indirect Employment (Unskilled labour)	P	NA	POSITIVE
		Loss of Employment (local labour)	HIGH	<p>SPDC shall</p> <ul style="list-style-type: none"> support entrepreneurial skill development and opportunities for community members to cushion the effect of reduction in economic/income generating activities. 	LOW
		Third party agitation	HIGH	<ul style="list-style-type: none"> SPDC shall discuss and agree on sustainable community development project and implement agreed projects, these will serve the whole fence line communities without bias. SPDC shall sign and implement GMoU with communities; SPDC shall sustain stakeholders engagement throughout the project lifecycle. SPDC shall ensure Infrastructural development via GMoU implementation 	LOW
		Crime and insecurity (Kidnapping, Hostage-taking, armed robbery, Militancy)	HIGH	<ul style="list-style-type: none"> SPDC shall advise the contractor to site recruitment office away from the work site to reduce job seekers at the site. SPDC shall ensure access control is implemented at work site SPDC shall implement proper journey management system. SPDC shall work with the Government, communities and other relevant agencies to improve security in the project area SPDC shall ensure that security orientation and awareness is conducted for workforce. SPDC shall ensure that security orientation and awareness is conducted for workforce. 	MEDIUM

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Project phase	Project activity	Description of impact	Identified potential Impact	Mitigation measures	Rating After Mitigation
		Increase in RTIs due to dust particles	HIGH	<ul style="list-style-type: none"> SPDC shall wet the site before excavation and construction to minimize dust. Health advise to the communities members (particularly the under aged) to stay away from construction site Access control to the project area should enforced 	LOW
		Social dislocation	HIGH	<ul style="list-style-type: none"> SPDC shall advise the contractor to site recruitment office away from the project site to reduce job seekers at the site. SPDC shall ensure access control is implemented at work site. SPDC shall ensure health awareness campaigns are conducted for workforce on the risks of STIs from the services of CSWs to discourage patronage 	LOW
		Increased exposure to carcinogenic substances	HIGH	<ul style="list-style-type: none"> SPDC shall ensure that only certified personnel handle radioactive materials. SPDC shall ensure that radioactive materials are stored safely. SPDC shall ensure toolbox talks are conducted before the commencement of the job SPDC shall ensure appropriate PPEs are used by the workers 	LOW
		Alcohol and drug abuse	HIGH	<ul style="list-style-type: none"> Ensure the implementation of the company's alcohol and drug policies. Carryout awareness campaign on alcohol and drug abuse in schools, churches and town halls to reduce alcohol intake in the communities. Pre-activity health/sex education campaign shall be conducted for both workforce and communities. 	LOW
Operation	Well work-over, Gas production,	Potential for environmental contamination due to gas leaks	HIGH	<p>SPDC shall ensure</p> <ul style="list-style-type: none"> Safety signage shall be deployed at strategic locations. Emergency response plan shall be in place Use of appropriate PPEs provision of adequate firefighting equipment 	LOW
	Pipeline maintenance & replacement	Increase in business opportunities	POSITIVE	NA	POSITIVE
		Increase in potential for injury/fatality of workforce & third parties	HIGH	<ul style="list-style-type: none"> Workers shall use appropriate PPEs (life jackets, work vests/ goggles etc) SPDC shall ensure first aid box on site and emergency response and medevac are in place Toolbox meetings shall be held before the start of daily tasks 	LOW

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Project phase	Project activity	Description of impact	Identified potential Impact	Mitigation measures	Rating After Mitigation
				<ul style="list-style-type: none"> ▪ Awareness shall be created among site workers on the likelihood of exposure to poisonous wildlife & plants ▪ Trained First Aiders shall form part of the workforce in the ratio of 1:25 ▪ Ensure adequate MEDEVAC and referral system 	
		Revenue generation for government and SPDC	POSITIVE	NA	POSITIVE
		Increase in potential for sabotage of facilities	HIGH	SPDC shall <ul style="list-style-type: none"> • Develop and implement a security management plan for the project • Ensure routine surveillance of facility 	LOW
		Reduction in gas flaring	POSITIVE	NA	POSITIVE
		Increase in diseases STIs HIV/AIDS	HIGH	<ul style="list-style-type: none"> ▪ Workers shall be encouraged to undergo voluntary counselling and testing in order to know their HIV status and in turn guide behaviour ▪ SPDC shall ensure condoms are provided for workers at the site clinic and distributed to the communities. ▪ SPDC shall enforce access control to base camps ▪ SPDC shall enforce Alcohol and drug policy in the camps /worksites as part of culture of health. 	LOW
		Prevalence in endemic diseases (Malaria, Typhoid, RTI)	HIGH	<ul style="list-style-type: none"> ▪ Carryout health education on the Rollback Malaria interventions. ▪ Ensure adequate referral system 	LOW
		Opportunity for contracting	POSITIVE	NA	POSITIVE
		Opportunity for direct and indirect Employment (Unskilled labour)	POSITIVE	NA	POSITIVE
		Third party agitation	HIGH	<ul style="list-style-type: none"> • SPDC shall discuss and agree on sustainable community development project and implement agreed projects, these will serve the whole fence line communities without bias. • SPDC shall sign and implement GMoU with communities; • SPDC shall sustain stakeholders engagement throughout the project lifecycle. • SPDC shall ensure Infrastructural development via PGMoU implementation 	LOW

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Project phase	Project activity	Description of impact	Identified potential Impact	Mitigation measures	Rating After Mitigation
		Crime and insecurity (Kidnapping, Hostage-taking, armed robbery, Militancy) and other social vices	HIGH	<ul style="list-style-type: none"> SPDC shall advise the contractor to site recruitment office away from the work site to reduce job seekers at the site. SPDC shall ensure access control is implemented at work site SPDC shall implement proper journey management system. SPDC shall work with the Government, communities and other relevant agencies to improve security in the project area SPDC shall ensure that security orientation and awareness is conducted for workforce. SPDC shall ensure that security orientation and awareness is conducted for workforce. 	LOW
		Waste generation (Scrap metals, Woods, Food waste)	HIGH	<ul style="list-style-type: none"> Waste management plans (in line with regulatory guidelines and SPDC procedures) shall be strictly adhered to during all phases of the project. Wastes shall be segregated at source into color-coded or labelled bins and disposed of in line with a project specific waste management plan. 	LOW
		Increased exposure to carcinogenic substances	HIGH	<ul style="list-style-type: none"> SPDC shall ensure that only certified personnel handle radioactive materials. SPDC shall ensure that radioactive materials are stored safely. SPDC shall ensure toolbox talks are conducted before the commencement of the job SPDC shall ensure appropriate PPEs are used by the workers 	LOW
		Alcohol and drug abuse	HIGH	<ul style="list-style-type: none"> Ensure the implementation of the company's alcohol and drug policies. Carryout awareness campaign on alcohol and drug abuse in schools, churches and town halls to reduce alcohol intake in the communities. Pre-activity health/sex education campaign shall be conducted for both workforce and communities. 	LOW
		Contamination of surface water/Sediment	HIGH	<ul style="list-style-type: none"> Waste management plans (in line with regulatory guidelines and SPDC procedures) shall be strictly adhered to during all phases of the project. Wastes shall be segregated at source into color-coded or labelled bins and disposed of in line with a project specific waste management plan. SPDC shall ensure that sewage wastes in base camps are properly managed (i.e. using a sewage treatment plant). 	LOW

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Project phase	Project activity	Description of impact	Identified potential Impact	Mitigation measures	Rating After Mitigation
				<ul style="list-style-type: none"> Safe Handling of Chemicals (SHOC) cards shall be visibly displayed at all sites where chemicals are handle Fuel, lube oils and chemicals shall be safely stored in containers in bonded areas. 	
Decommissioning and abandonment	<ul style="list-style-type: none"> Flushing of pipelines Vacuum drying of pipeline Capping of pipeline Removal of surface installations Plugging of wells Site restoration Return of land to owner(s) 	Increase in potential for soil and water contamination	HIGH	SPDC shall ensure: <ul style="list-style-type: none"> all wastes are properly segregated and contained before disposal all wastes are properly disposed of and monitored from cradle to grave All effluents are treated to regulatory limits before discharge 	LOW
		Increase in litigation potential	HIGH	<ul style="list-style-type: none"> The relevant stakeholders/legacy issues shall be identified Regular consultation with stakeholders (Govt., Community, NGOs, CBOs etc.) shall be undertaken. Project Advisory Committee (PAC) shall be set up to guide MOU implementation and address issues/concerns 	LOW
		Loss of job by community surveillance team	HIGH	SPDC shall <ul style="list-style-type: none"> support entrepreneurial skill development and opportunities for community members to cushion the effect of reduction in economic/income generating activities. 	LOW
		Increase in usable land resource to the community	POSITIVE	NA	POSITIVE
		Opportunity for contracting	POSITIVE	NA	POSITIVE
		Opportunity for direct and indirect Employment (Unskilled labour)	POSITIVE	NA	POSITIVE
		Third party agitation	HIGH	<ul style="list-style-type: none"> SPDC shall discuss and agree on sustainable community development project and implement agreed projects, these will serve the whole fence line communities without bias. SPDC shall sign and implement GMoU with communities; SPDC shall sustain stakeholders engagement throughout the project lifecycle. SPDC shall ensure Infrastructural development via GMoU implementation 	LOW
		Crime and insecurity (Kidnapping, Hostage-taking, armed robbery, Militancy) and other social vices	HIGH	<ul style="list-style-type: none"> SPDC shall advise the contractor to site recruitment office away from the work site to reduce job seekers at the site. 	LOW

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Project phase	Project activity	Description of impact	Identified potential Impact	Mitigation measures	Rating After Mitigation
				<ul style="list-style-type: none"> • SPDC shall ensure access control is implemented at work site • SPDC shall implement proper journey management system. • SPDC shall work with the Government, communities and other relevant agencies to improve security in the project area • SPDC shall ensure that security orientation and awareness is conducted for workforce. • SPDC shall ensure that security orientation and awareness is conducted for workforce. 	
		Waste generation (Scrap metals, Woods, Food waste)	HIGH	<ul style="list-style-type: none"> ▪ SPDC and contractors shall ensure that all wastes are segregated and managed according to EGASPIN and FMEEnv guidelines ▪ Enforce access control to ensure that wastes are not indiscriminately transferred from one place to the other by members of the communities in the act of picking properties. ▪ Ensure proper documentation of the quantity of waste from generated site to disposal point 	LOW
		Increased exposure to carcinogenic substances	HIGH	<ul style="list-style-type: none"> ▪ SPDC shall carryout awareness campaign in educating the communities members to keep the required distance when rays are being used for welding joints and other radioactive services. ▪ SPDC shall ensure that the emergency contingencies are in place to address any spill to minimise contamination of food and water sources. 	LOW
		Alcohol and drug abuse	HIGH	<ul style="list-style-type: none"> ▪ Ensure the implementation of the company’s alcohol and drug policies 	LOW
		Prevalence of STIs HIV/AIDS	HIGH	<ul style="list-style-type: none"> ▪ SPDC shall enforce access control to base camps ▪ SPDC shall enforce Alcohol and drug policy in the camps /worksite as part of culture of health. 	LOW

CHAPTER SEVEN

ENVIRONMENTAL MANAGEMENT PLAN

7.1: Introduction

Environmental management is concerned with a planned and integrated programme aimed at ensuring that adverse impacts of a proposed project are contained and brought to acceptable minimum levels, while the positive impacts are enhanced to optimize the benefits. Environmental management provides confidence on the part of project planners that a reliable scheme has been put in place to deal with any contingency that may arise during all phases of the project development, from mobilization to abandonment. In keeping with SPDC's policy on the environment, considerations of environmental implications of this project began from feasibility study, conceptual design and will continue throughout the project life cycle.

Environmental management will be carried out in accordance with the provisions of ISO 14001, sections 4.3.2 to 4.3.4, which are reflected in SPDC HSSE & SP Control Framework (HSSE & SP CF). The HSE-MS addresses the overall approach adopted for management of HSE risks through the project development phases by the project management team. HSE-MS document provides central guidance and co-ordination for project-wide documents - work procedures, standards, work practices, etc., and demonstrates how the Hazards and Effects Management Process (HEMP) will be applied on the project such that HSE risks are kept As Low As Reasonably Practicable (ALARP). Good environmental management, which is part of SPDC's HSE-MS goals, has the following long term objectives:

- Ensure compliance with Legislations and Company policy;
- Achieve, enhance and demonstrate sound environmental performance built around the principle of continuous improvement;
- Provide strategy for overall planning, operation, audit and review;
- Enable project planners establish environmental priorities.

To provide assurance that the risk management and control procedures identified are implemented, a comprehensive EMP was developed (Table 7.2) for utilization throughout the project life cycle.

7.2: SPDC's Corporate HSE Programme

It is the policy of Shell companies to conduct their activities in such a way as to take foremost account of the health and safety of all their employees and other persons, and to give proper regards to the conservation of the environment. In implementing this policy, Shell companies not only comply with the requirements of the relevant legislations but promote, in an appropriate manner, measures for the protection of health, safety, environment and the security of all who may be involved directly or indirectly with their activities. The Environmental Management activities initiated by SPDC are intended to implement the above policy and the policy will be applied to all stages of the project life cycle. The projects' HSE-MS is fully aligned to SPDC's corporate HSE programs.

7.3: Monitoring Objectives

The following monitoring objectives are established:

- to create local data bank on the impacts of project activities on the environment, for future development of predictive models;
- to monitor emissions and discharges at all stages of project development to ensure they meet national standards;
- to determine whether environmental changes are results of development or a result of natural variations;
- to determine the effectiveness of the mitigation measures;
- to determine long term impacts.
- to determine the duration of return to normalcy of the environmental components of the project area .

7.4: Resourcing

Shell Petroleum Development Company (SPDC) considers environmental management as an important aspect of project procedures. Consequently, in any project for which project management team is set up, an environmental specialist always forms an integral part of the team. In this project, an environmental focal point has been appointed to liaise between the project managers and the environmental specialist, consultants as well as advises on all environmental issues in conformity with SPDC's HSE policy. Shell Petroleum Development Company (SPDC) recognizes the need to use external environmental consultants to supplement in-house environmental specialists. To this end, the environmental consultants will continue to provide expert advice to the SPDC environmental managers throughout the Life cycle of this project.

7.5: Environmental Audits

Shell Petroleum Development Company (SPDC) has an audit scheme, as part of its programme on environmental management. The scheme is aimed at verifying the effectiveness of environmental control and highlighting areas of weakness in environmental management requiring further improvements. The audits are focused on areas of project perceived as having the highest environmental impacts. It is recognized that to be truly effective, these audits need to be conducted within the overall structured management systems. The structured approach is aimed at disseminating information, providing advice and assistance in its application, and at corporate assurance of performance in meeting the environmental requirement/targets. External audits are also carried out for SPDC assets and projects and SPDC subscribes to ISO 14001 standards.

7.6: Responsibilities and Training

Within SPDC, environmental protection, like safety, is a line responsibility for which staff, at all levels, have accountabilities. An environmental specialist assists the line management with advice on environmental matters, from an expert point of view. However, responsibility and accountability is clearly defined, from senior management who allocate resources and monitor environmental performance to individual contractors who have responsibility for environmentally

sound practices in their workplace. All staff will be made aware of their responsibilities through induction and training opportunities as outlined in the projects' HSE-MS document. In addition, procedures, guidelines and notices will advise staff on how to respond in the event of an environmental emergency. The Shell Corporate Environment Department is responsible for internal and facilitating external monitoring and auditing the environmental activities of this project.

7.7: Waste Management

The Waste Management Plan includes procedures for safe handling, control and disposal of generated waste in accordance with the SPDC procedure. Wastes emanating from all phases of the Enwhe FDP (premobilization, mobilization, construction, demobilization, operation and decommissioning) activities are mainly food wastes, garbage, shrubs/vegetation, scrap metals, woods, waste papers etc. These wastes are handled in compliance with the Petroleum (Drilling & Productions) Regulations, 1969, Sections 25, 36 49 and (b), (c) and (d), which stipulate *inter alia* that:

The licensee or lessee shall adopt all practical precautions, including the provision of up-to-date equipment to prevent the pollution of inland waters, rivers, creeks, water courses, the territorial waters of Nigeria or the high seas by oil, mud or other fluids or substances which might contaminate the water or marine life, and where any such pollution occurs or has occurred, shall take prompt steps to control and, if possible, end it."

The waste management strategy to be adopted in the proposed project has been highlighted in Section 3.5 of chapter three.

7.8: Emergency Response Programme

In compliance with all regulatory standards, as well as Health, Safety, Environment and Security (HSES) procedures shall form the basis for the execution of the project. However, emergency situations could still occur as a result of equipment failure, negligence and/or sabotage. Consequently, a site-specific contingency plan shall be developed as back up to site specific emergency response systems which shall be put in place to handle any incident emergency. As a minimum, the contingency plans that shall apply shall address the following emergency situations:

- Fires and explosions;
- Serious injury or illness;
- Road and water mishaps.

In order to accomplish the above targets, the EMP has considered each environmental, social and health impacts and parameters for their monitoring. It also specifies the responsible party/parties for each action, responsible party as well as parameters for monitoring.

7.9: Contractor Management

The contractor staff shall be well informed and trained on the HSE policies and guidelines and be made aware of SPDC's HSE performance targets including the 12 Life Saving Rules. All activities shall be executed within the confines of relevant legislation and stakeholders' interests. Contractors shall provide adequate health services as well as site first aid services for its workforce. The first aid services shall be extended to visiting personnel. All project activities shall be properly managed through careful planning and the application of relevant HSE policies including the following:

- Enforcement of 12 Life Saving Rules.
- Job Hazard Analysis and toolbox meetings;
- Regular emergency drills;

Table 7.1: Environmental Monitoring Plan

Environmental component	ASSOCIATED LIMITATIONS		MONITORING PROGRAMME			
	Regulation/ Standard	Requirements/ Limits	Parameters to be monitored	Sampling Location	Frequency during Project Life cycle.	Data collection method
Air Quality	DPR EGASPIN III E 4.4.5 Table III-3 National Ambient Air Quality Standards	Daily average mean ($\mu\text{g}/\text{m}^3$) Total SPM: 60-90 Carbon monoxide: 10 SO ₂ : 100-150 NO ₂ : 150 Lead: 0.08ppm	Particulates, NO ₂ , SO ₂ , CO, H ₂ S, NH ₃ , Noise levels, heavy and trace metals in ambient air VOC	During well drilling During pipeline laying	Weekly	In-situ measurement using Air Quality Meters
Soil	Baseline data	-	pH, Heavy metals and Organics	Around Chemical/Gasoline storage area during pipeline laying activities	Construction phase	Sample collection and analysis in an external approved laboratory.
Surface water (Recipient water)	Baseline data	-	p H, TSS, Turbidity, Heavy metals and Organics	Upstream and downstream of Pipeline river crossings	Construction phase	Sample collection and analysis in an external approved laboratory.
Ground water	Baseline data		Heavy metals	Around NAG wells during drilling	Monthly during drilling phase	

Table 7.2: Environmental Management Plan for the Cumulative impact/effects of the Enwhe FDP

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact	Parameter for Monitoring	Frequency of Monitoring/ Formal Reporting	Responsible/ Action Party
Pre-mobilization	<ul style="list-style-type: none"> • Consultation, • Land acquisition and • Compensation, Resolution of legacy issues 	Increase in project awareness	HIGH	<ul style="list-style-type: none"> • SPDC shall ensure adequate consultation with all stakeholders especially communities. • SPDC shall carry out sound community sensing to evaluate existing relationship between SPDC & fence line communities, collate legacy projects & agree with community on ways of addressing them to change the perception to positive. 	LOW	Stakeholders' engagement reports/agreement	Quarterly	SPDC: Central Hub Asset Manager Regulators; FMEEnv, DPR and all Relevant state and Federal Environmental Regulatory bodies
		Anticipated Loss of land associated resources	HIGH	<ul style="list-style-type: none"> • Land take shall be limited to the minimum required. • SPDC shall ensure consultation is done with the right responsible persons. 	LOW	Site inspection report Vegetation studies report	Biannually	SPDC: Central Hub Asset Manager Regulators; FMEEnv, DPR and all Relevant state and Federal Environmental Regulatory bodies
		Financial enhancement	POSITIVE	<ul style="list-style-type: none"> • SPDC shall discuss and agree on sustainable community development project and implement agreed projects, these will serve the whole fence line communities without bias. • SPDC shall sign and implement GMoU with communities; • Stakeholder's engagement shall be sustained through the project lifecycle. • SPDC shall encourage Infrastructural development via GMoU implementation 	LOW	GMoU Community Engagement reports	Annually	SPDC: Central Hub Asset Manager Regulators; FMEEnv, DPR and all Relevant state and Federal Environmental Regulatory bodies
		Third party agitation	HIGH	<ul style="list-style-type: none"> • Relevant stakeholders/legacy issues shall be identified. • Regular consultation with stakeholders (Govt., 	LOW	Employment records	Quarterly	Central Hub SPDC: Central Hub Asset Manager

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Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact	Parameter for Monitoring	Frequency of Monitoring/ Formal Reporting	Responsible/ Action Party
				Community, NGOs, CBOs etc.) shall be carried out to understand community perceptions, issues and concerns <ul style="list-style-type: none"> • Effective liaison/communication channels (CICs) from the communities to the project execution team shall be established. • Project Advisory Committee (PAC) to guide MoU implementation shall be set up 		Community Engagement reports		Regulators; FMEEnv, DPR and all Relevant state and Federal Environmental Regulatory bodies
Mobilization	<ul style="list-style-type: none"> • Movement of equipment and personnel, • Rig movement 	Loss of livelihood	HIGH	<ul style="list-style-type: none"> • Alternative income generating activities through skills acquisition that will empower communities shall be supported. • SPDC shall encourage skills acquisition and training programmes 	LOW	Inspection records Employment records Community Engagement reports	Annually	SPDC: Central Hub Asset Manager Regulators; FMEEnv, DPR and all Relevant state and Federal Environmental Regulatory bodies
		Increase in road traffic, potential for accidents and injuries	HIGH	<ul style="list-style-type: none"> ▪ Visible warning signs shall be placed at strategic positions along the roads ▪ SPDC shall ensure there is traffic control at strategic points along the road ▪ SPDC shall ensure all vehicles observe the speed limits and large vehicles have warning lights to alert other road users ▪ SPDC shall ensure all project vehicles are pre-mobbed and certified. ▪ Reverse alarm shall be installed in all Operational vehicles ▪ Speed control facilities such as IVMS and Strata shall be installed in all vehicle 	LOW	Site inspection/ stakeholder engagement reports IVMS checks/Reports Inventory of approved journey management forms	Quarterly	SPDC: Central Hub Asset Manager Regulators; FMEEnv, DPR and all Relevant state and Federal Environmental Regulatory bodies

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Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact	Parameter for Monitoring	Frequency of Monitoring/ Formal Reporting	Responsible/ Action Party
				<ul style="list-style-type: none"> ▪ The 12 Life Saving Rules (LSR) shall be enforced on all road users. ▪ Effective journey Management system ▪ Proper Risk Assessment (using JHA and Toolbox meeting) before work begins 				
		Damage to road infrastructure	HIGH	<ul style="list-style-type: none"> ▪ SPDC shall construct roads to its location where they do not exist and maintain existing roads to its location without refusing the general public from using same. 	LOW	Site inspection Inventory of approved Journey Management forms	Quarterly	SPDC: Central Hub Asset Manager Regulators; FMEEnv, DPR and all Relevant state and Federal Environmental Regulatory bodies
		Influx of people causing Pressure on health and other Infrastructure	HIGH	<ul style="list-style-type: none"> ▪ SPDC shall advise the contractor to locate recruitment office away from the work site to reduce job seekers at the site. ▪ Workers camps shall be provided for the workforce by the Contractor to reduce the pressure on housing. ▪ SPDC shall ensure access control is implemented at work site ▪ Patronage of commercial sex workers by workforce shall be discouraged through health awareness campaigns to be conducted by SPDC. ▪ SPDC shall ensure unskilled and where feasible semi-skilled workers are sourced from immediate communities. ▪ SPDC shall honour all GMoU agreements ▪ SPDC and contractor shall provide for health care needs of workforce outside of those in the community. 	LOW	Site inspection report	Biannually	SPDC: Central Hub Asset Manager Regulators; FMEEnv, DPR and all Relevant state and Federal Environmental Regulatory bodies

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				<ul style="list-style-type: none"> SPDC shall avoid the use of the communities' welfare facilities such as water, and Health facilities. 				
		Increase in sexually transmitted disease and other communicable diseases	HIGH	<ul style="list-style-type: none"> Workers shall be encouraged to undergo voluntary counselling and testing in order to know their HIV status and in turn guide behaviour SPDC shall enforce access control to base camps. SPDC shall enforce Alcohol and drug policy in the camps /worksites as part of culture of health. 	LOW	Reports on community engagement sessions Health Report Site inspection report/tool box meetings	Quarterly	SPDC: Central Hub Asset Manager Regulators; FMEEnv, DPR and all Relevant state and Federal Environmental Regulatory bodies
		Reduction in air quality	HIGH	<ul style="list-style-type: none"> SPDC shall ensure the use of sprinklers with high pressure water guns to minimize dust. Health advise to the communities members (particularly the under aged) to stay away from construction site Access control to the project area should enforced. 	LOW	<ul style="list-style-type: none"> Pre-mob certificates Vehicle Maintenance records 	Weekly	SPDC: Central Hub Asset Manager Regulators; FMEEnv, DPR and all Relevant state and Federal Environmental Regulatory bodies
		Loss of vegetation and wildlife	HIGH	<ul style="list-style-type: none"> SPDC shall restrict project activities to within agreed scope and establish bond walls / fencing to avoid encroachment into unplanned zones. Any vegetation cleared in the lay-down area shall be re-planted with native species. 	LOW	Inspection records Site incident report	Biannually	SPDC: Central Hub Asset Manager Regulators; FMEEnv, DPR and all Relevant state and Federal Environmental Regulatory bodies
		Habitat fragmentation	HIGH	<ul style="list-style-type: none"> Clearing should be limited to areas of operation. Wildlife reserves and sacred forests shall be identified and avoided. Re-vegetation shall be undertaken after the project work where desirable. 	LOW	Fragmentation index, Biodiversity reports, wildlife migration pattern	Annually	SPDC: Central Hub Asset Manager Regulators; FMEEnv, DPR and all Relevant state and Federal Environmental Regulatory bodies

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		Loss of aquatic species (Fisheries, Planktons and benthic fauna)	HIGH	<ul style="list-style-type: none"> • SPDC shall establish skill acquisition / training scheme. • SPDC shall implement Biodiversity Action Plan of the Gbaran Ubie IOGP. • Research and development shall be encouraged to prevent habitat alteration to the barest minimum. 	LOW	<ul style="list-style-type: none"> • Site inspection reports • Environmental Compliance Monitoring report 	Biannually	SPDC: Central Hub Asset Manager Regulators; FMEEnv, DPR and all Relevant state and Federal Environmental Regulatory bodies
		Distortion of aquatic environment (physical components)	HIGH	<ul style="list-style-type: none"> • SPDC shall establish skill acquisition / training scheme. • SPDC shall implement Biodiversity Action Plan of the Gbaran Ubie IOGP. • Research and development shall be encouraged to prevent habitat alteration to the barest minimum. 	LOW	<ul style="list-style-type: none"> • Site inspection reports • Environmental Compliance Monitoring report 	Biannually	SPDC: Central Hub Asset Manager Regulators; FMEEnv, DPR and all Relevant state and Federal Environmental Regulatory bodies
		Increase in noise and vibration	HIGH	<ul style="list-style-type: none"> ▪ Mufflers shall be installed on machineries and low noise generators shall be used. ▪ Noise level shall be monitored to ensure safe levels are not exceeded. ▪ There shall be no night work 	LOW	<ul style="list-style-type: none"> • Pre-mob certificates • Maintenance records • Evidence of issuance of PPEs • Site inspection reports 	Quarterly	SPDC: Central Hub Asset Manager Regulators; FMEEnv, DPR and all Relevant state and Federal Environmental Regulatory bodies
		Increase in refined hydrocarbon contents of soil and vegetation	HIGH	<ul style="list-style-type: none"> • SPDC shall ensure fuel bunkering is done within stipulated bonded area that is leak proof to avoid contamination. • SPDC shall encourage regular servicing of vehicles to reduce emissions from exhaust. • Vehicles should fuel and refuel at designated stations. 	LOW	<ul style="list-style-type: none"> • Pre-mob certificates • Maintenance records • Evidence of issuance of PPEs • Site inspection reports 	Quarterly	SPDC: Central Hub Asset Manager Regulators; FMEEnv, DPR and all Relevant state and Federal Environmental Regulatory bodies
		Increase in crime rate	HIGH	<ul style="list-style-type: none"> • SPDC shall advise the contractor to site recruitment 	MEDIUM	<ul style="list-style-type: none"> • Evidence of stakeholders 	Quarterly	SPDC: Central Hub Asset Manager

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				office away from the work site to reduce job seekers at the site. <ul style="list-style-type: none"> • SPDC shall ensure access control is implemented at work site • SPDC shall implement proper journey management system. • SPDC shall work with the Government, communities and other relevant agencies to improve security in the project area • SPDC shall ensure that security orientation and awareness is conducted for workforce. • SPDC shall ensure that security orientation and awareness is conducted for workforce. 		<ul style="list-style-type: none"> • engagements • Records of security incidences • Project security plan • Record of security orientation and awareness 		Regulators; FMEEnv, DPR and all Relevant state and Federal Environmental Regulatory bodies
		Loss of cultural/heritage sites	MEDIUM	<ul style="list-style-type: none"> • Historical sites/sacred places, fishing sites/grounds and other areas of interest to the communities shall be avoided during land acquisition, and where unavoidable, agreements shall be reached with the respective communities & duly compensated for. • Designate authentic shrines as protected cultural properties 	LOW	Community engagement sessions Site inspection report	Annually	SPDC: Central Hub Asset Manager Regulators; FMEEnv, DPR and all Relevant state and Federal Environmental Regulatory bodies
		Soil compaction	LOW	<ul style="list-style-type: none"> • SPDC shall ensure that there is restriction to permanent wheel tracks. • SPDC shall ensure trucks avoid waterlogged routes. 	LOW	<ul style="list-style-type: none"> • Site inspection reports Environmental Compliance Monitoring report	Monthly	SPDC: Central Hub Asset Manager Regulators; FMEEnv, DPR and all Relevant state and Federal Environmental Regulatory bodies
		Increase in waste	HIGH	<ul style="list-style-type: none"> ▪ SPDC and contractors shall ensure that all wastes are segregated and managed according to EGASPIN/FMEEnv. 	LOW	Waste consignment note	Monthly	SPDC: Central Hub Asset Manager Regulators; FMEEnv, DPR and all Relevant state and Federal

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				<ul style="list-style-type: none"> Ensure proper documentation of the quantity of waste from generated site to disposal point 		Monitoring of recipient environment in line with EGASPIN 2002		Environmental Regulatory bodies
Construction	Wells/locations/pipe lines <ul style="list-style-type: none"> Route & location clearing Dredging, Pipeline river crossing, Pilling, Concrete and asphalt works, Excavation Backfilling Pipeline coating Stringing & welding; NDT and cathodic protection Base camp activities 	Increase in respiratory tract infection	HIGH	<ul style="list-style-type: none"> SPDC shall wet the site before excavation and construction to minimize dust. Health advise to the communities members (particularly the under aged) to stay away from construction site Access control to the project area should enforced 	LOW	Medical records Awareness records	Annually	SPDC: Central Hub Asset Manager Regulators; FMEEnv, DPR and all Relevant state and Federal Environmental Regulatory bodies
		Land take	MEDIUM	<ul style="list-style-type: none"> Land take shall be limited to the minimum required. SPDC shall ensure consultation is done with the right responsible persons 	LOW	<ul style="list-style-type: none"> Site inspection reports Evidence of support for farmer groups and cooperatives 	Annually	SPDC: Central Hub Asset Manager Regulators; FMEEnv, DPR and all Relevant state and Federal Environmental Regulatory bodies
		Increase in population due to influx of persons	HIGH	<ul style="list-style-type: none"> SPDC shall advise the contractor to site recruitment office away from the work site to reduce job seekers at the site. SPDC shall ensure access control is implemented at work site SPDC shall ensure health awareness campaigns are conducted for workforce on the risks of STIs from the services of CSWs to discourage patronage SPDC shall ensure unskilled and where feasible semi-skilled 	LOW	Community engagement report Site inspection reports	Quarterly	Central Hub SPDC: Central Hub Asset Manager Regulators; FMEEnv, DPR and all Relevant state and Federal Environmental Regulatory bodies

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				<ul style="list-style-type: none"> workers are sourced from immediate communities • SPDC shall support existing health facilities upgrade and staff training. • SPDC will house workers in camps to reduce pressure and local housing stock. • SPDC shall comply with local content policy. 				
		Increase in social vices (Alcohol and drug abuse, CSWs)	HIGH	<ul style="list-style-type: none"> ▪ Ensure the implementation of the company's alcohol and drug policies ▪ Pre-activity health/sex education campaign shall be conducted for both workforce and communities. 	LOW	<ul style="list-style-type: none"> Reports on community engagement sessions Site inspection report/tool box meetings 	Quarterly	SPDC: Central Hub Asset Manager Regulators; FMEnv, DPR and all Relevant state and Federal Environmental Regulatory bodies
		Crime and insecurity (Kidnapping, Hostage-taking, armed robbery, Militancy)	HIGH	<ul style="list-style-type: none"> • SPDC shall advise the contractor to site recruitment office away from the work site to reduce job seekers at the site. • SPDC shall ensure access control is implemented at work site • SPDC shall implement proper journey management system. • SPDC shall work with the Government, communities and other relevant agencies to improve security in the project area • SPDC shall ensure that security orientation and awareness is conducted for workforce. • SPDC shall ensure that security orientation and awareness is conducted for workforce. 	MEDIUM	<ul style="list-style-type: none"> • Evidence of stakeholders engagements • Records of security incidences • Project security plan • Record of security orientation and awareness 	Quarterly	SPDC: Central Hub Asset Manager Regulators; FMEnv, DPR and all Relevant state and Federal Environmental Regulatory bodies

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		Injury/fatality of workforce and/or third party	HIGH	<ul style="list-style-type: none"> SPDC shall enforce the use of appropriate PPEs (life jackets, work vests/ goggles etc). SPDC shall ensure first aid box on site and emergency response and med-rescue/medevac are in place. Toolbox meetings shall be held before the start of daily tasks Awareness shall be created among site workers on the likelihood of exposure to poisonous wildlife & plants. Trained First Aiders shall form part of the workforce SPDC policy on road traffic journey management shall be adhered to (all journey must be approved, no night journeys, speed limits on land) 	LOW	Competence certification of workforce Emergency response plan HAZID register Pep-talk records	Quarterly	SPDC: Central Hub Asset Manager Regulators; FMEEnv, DPR and all Relevant state and Federal Environmental Regulatory bodies
		Road traffic disruption	HIGH	SPDC shall upgrade existing roads to suite the anticipated project activities and additional access road provided, where necessary	LOW	<ul style="list-style-type: none"> Journey management records Pre-mob certificates Pep-talk records Certificate of defensive driving Vehicle Monitoring Analysis 	Weekly	SPDC: Central Hub Asset Manager Regulators; FMEEnv, DPR and all Relevant state and Federal Environmental Regulatory bodies
		Increase in volume of wastes	HIGH	<ul style="list-style-type: none"> SPDC and contractors shall ensure that all wastes are segregated and managed according to EGASPIN/FMEEnv guidelines. 	LOW	Waste consignment note	Monthly	SPDC: Central Hub Asset Manager Regulators; FMEEnv, DPR and all Relevant state and Federal

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				<ul style="list-style-type: none"> ▪ Health Education for members of the communities on the management of waste. ▪ Ensure proper documentation of the quantity of waste from generated site to disposal point 		Environmental compliance monitoring report		Environmental Regulatory bodies
		Increase in employment/business opportunities	POSITIVE	NA	POSITIVE	-	-	-
		Shift from traditional occupations	HIGH	<ul style="list-style-type: none"> • SPDC shall discuss and agree on sustainable community development project and implement agreed projects. 	LOW	Status report on traditional occupation Implement GMoU	Annually	SPDC: Central Hub Asset Manager Regulators; FMEEnv, DPR and all Relevant state and Federal Environmental Regulatory bodies
		Inflation	HIGH	<ul style="list-style-type: none"> • Alternative income generating activities through skills acquisition that will empower communities shall be introduced and supported by SPDC and Contactors. • SPDC and Contractors shall provide accommodation for operational staff at the base camps and provide catering services. 	LOW	Implement GMoU	Annually	SPDC: Central Hub Asset Manager Regulators; FMEEnv, DPR and all Relevant state and Federal Environmental Regulatory bodies
		Gender imbalance	HIGH	<ul style="list-style-type: none"> • SPDC shall enforce existing laws against gender-based employment discrimination and against sexual harassment. • SPDC shall Increase mentorship and other efforts to boost the number of women in traditionally male occupations. 	LOW	Evidence of stakeholders engagements	Annually	SPDC: Central Hub Asset Manager Regulators; FMEEnv, DPR and all Relevant state and Federal Environmental Regulatory bodies
		Potential for skills acquisition	P	NA	POSITIVE	-	-	-
		Pressure on existing infrastructure and services (Water, Electricity,	HIGH	<ul style="list-style-type: none"> ▪ SPDC shall advise the contractor to locate recruitment office away from 	LOW	Site inspection report	Annually	SPDC: Central Hub Asset Manager Regulators; FMEEnv, DPR and all Relevant

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		Recreational facilities, Health facilities, Roads and others)		the work site to reduce job seekers at the site <ul style="list-style-type: none"> ▪ Workers camps shall be provided for the workforce by the Contractor to reduce the pressure on housing. ▪ SPDC shall ensure access control is implemented at work site ▪ Patronage of commercial sex workers by workforce shall be discouraged through health awareness campaigns to be conducted by SPDC. ▪ SPDC shall ensure unskilled and where feasible semi-skilled workers are sourced from immediate communities. ▪ SPDC shall honour all GMOU agreements ▪ SPDC and contractor shall provide for health care needs of workforce outside of those in the community. ▪ Construction should be done in phases so as to reduce the number of workers at site in any particular time ▪ Health education on communicable disease transmissions. 				state and Federal Environmental Regulatory bodies
		Increase in communicable diseases, STIs HIV/AIDS	HIGH	<ul style="list-style-type: none"> ▪ Workers shall be encouraged to undergo voluntary counselling and testing in order to know their HIV status and in turn guide behaviour ▪ SPDC shall enforce access control to base camps ▪ SPDC shall enforce Alcohol and drug policy in the camps /worksite as part of culture of health. 	LOW	Medical records Access Control/ID card Awareness records	Annually	SPDC; Central Hub Asset Manager Regulators; FMEEnv, DPR and all Relevant state and Federal Environmental Regulatory bodies

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		Change in topography	HIGH	<ul style="list-style-type: none"> Trenching shall be limited to the minimum size required and excavated sand managed properly. Fill material for sand filling shall be sourced from BYSMENV approved sites 	LOW	Site inspection report	Quarterly	SPDC: Central Hub Asset Manager Regulators; FMEEnv, DPR and all Relevant state and Federal Environmental Regulatory bodies
		Surface water pollution/distortion (increase in turbidity and Total Suspended Solids)	HIGH	SPDC shall deploy the most appropriate technology (silt curtain), to minimize loss of benthic organisms.	LOW	Environmental Compliance monitoring report Site inspection report	Quarterly	SPDC: Central Hub Asset Manager Regulators; FMEEnv, DPR and all Relevant state and Federal Environmental Regulatory bodies
		Soil pollution	HIGH	<ul style="list-style-type: none"> Wastes shall be segregated at source into color-coded or labelled bins and disposed of in line with a project specific waste management plan. Safe Handling of Chemicals (SHOC) cards shall be visibly displayed at all sites where chemicals are handled Fuel, lube oils and chemicals shall be safely stored in containers in bunded areas 	LOW	Site inspection report ECM report	Quarterly	SPDC: Central Hub Asset Manager Regulators; FMEEnv, DPR and all Relevant state and Federal Environmental Regulatory bodies
		Loss of biodiversity and Distortion of food chain (Economic trees)	HIGH	<ul style="list-style-type: none"> Any vegetation cleared in the lay-down area shall be re-planted with native species. SPDC shall ensure awareness campaigns are conducted for the workforce on the need to preserve the environment. Route clearing shall be done in stages to allow mobile fauna escape from the project area. 	LOW	Inspection records Site incident report Environmental Compliance monitoring report	Annually	SPDC: Central Hub Asset Manager Regulators; FMEEnv, DPR and all Relevant state and Federal Environmental Regulatory bodies
		Impairment/Loss of aquatic life (Loss of juvenile fishes due to gill damage from silt particles)	HIGH	SPDC shall deploy the most appropriate technology (silt curtain), to minimize loss of benthic organisms and fishery resources.	LOW	Inspection records Environmental compliance	Quarterly	SPDC: Central Hub Asset Manager Regulators; FMEEnv, DPR and all Relevant state and Federal

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						monitoring report Site incident report		Environmental Regulatory bodies
		Increase in disease vectors	HIGH	<ul style="list-style-type: none"> ▪ SPDC shall assist the communities in pest control measures ▪ Health education on the Health Implication of Rodents/other disease vectors in their homes. ▪ SPDC shall ensure that waste generated from the project during the period of construction are managed from cradle to grave. ▪ Health education on the consumption of rodents shall be provided by appropriate health authorities 	LOW	Pep Talks/tool box meetings Health Records for all the workforce	Monthly Annually	SPDC: Central Hub Asset Manager Regulators; FMEEnv, DPR and all Relevant state and Federal Environmental Regulatory bodies
		Blockage of natural water courses	HIGH	SPDC shall ensure that no natural water course is unduly obstructed /blocked during the implementation of the project, equalization culverts shall be installed where necessary.	LOW	Inspection records Site incident report	Quarterly	SPDC: Central Hub Asset Manager Regulators; FMEEnv, DPR and all Relevant state and Federal Environmental Regulatory bodies
		Increase in road traffic/ potential for accidents and injuries	HIGH	<ul style="list-style-type: none"> • Road safety awareness campaigns for both workers and the community. • Medical facilities shall be provided on-site with critical cases transferred to retainer clinics in Yenagoa or Port Harcourt. • SPDC shall ensure Med-rescue/medevac services are adequate and in place. • Visible warning signs shall be placed at strategic positions along the roads. 	LOW	<ul style="list-style-type: none"> • Journey management records • Pre-mob certificates • Pep-talk records • Certificate of defensive driving 	Weekly	SPDC: Central Hub Asset Manager Regulators; FMEEnv, DPR and all Relevant state and Federal Environmental Regulatory bodies

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				<ul style="list-style-type: none"> • SPDC shall ensure there is traffic control at strategic points along the road. • SPDC shall ensure all vehicles observe the speed limits and large vehicles have warning lights to alert other road users. • SPDC shall ensure all project vehicles are pre-mobbed and certified 		<ul style="list-style-type: none"> • Vehicle Monitoring Analysis 		
		Food insecurity	HIGH	<ul style="list-style-type: none"> ▪ Livewire Program shall be introduced for the youths in the communities 	LOW	Shell briefing note	Annually	SPDC: Central Hub Asset Manager Regulators; FMEEnv, DPR and all Relevant state and Federal Environmental Regulatory bodies
		Erosion	HIGH	SPDC shall ensure that no natural water course is unduly obstructed/blocked during the implementation of the project, equalization culverts shall be installed.	LOW	Inspection records Site incident report	Annually	SPDC: Central Hub Asset Manager Regulators; FMEEnv, DPR and all Relevant state and Federal Environmental Regulatory bodies
		Loss of fish breeding sites and migratory routes	HIGH	<ul style="list-style-type: none"> • SPDC shall reduce vegetation clearing to the minimum. • SPDC shall implement the Biodiversity Action Plan • SPDC shall optimize the existing pipelines RoW and roads. 	LOW	Site incident report	Bi-annually	SPDC: Central Hub Asset Manager Regulators; FMEEnv, DPR and all Relevant state and Federal Environmental Regulatory bodies
		Noise and vibration	HIGH	<ul style="list-style-type: none"> ▪ Mufflers shall be installed on machineries and low noise generators shall be used. ▪ Noise level shall be monitored to ensure safe levels are not exceeded. ▪ There shall be no night work 	LOW	<ul style="list-style-type: none"> • Pre-mob certificates • Maintenance records • Evidence of issuance of PPEs • Environmental compliance 	Weekly	Central Hub Asset Manager

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						monitoring report		
		Reduction in air quality	HIGH	<ul style="list-style-type: none"> SPDC shall wet the site before excavation and construction to minimize dust. Health advise to the communities members (particularly the under aged) to stay away from construction site Access control to the project area shall be enforced. 	LOW	<ul style="list-style-type: none"> Pre-mob certificates Vehicle Maintenance records Environmental compliance monitoring report 	Weekly	SPDC: Central Hub Asset Manager Regulators; FMEnv, DPR and all Relevant state and Federal Environmental Regulatory bodies
		Opportunity for direct and indirect Employment	POSITIVE	NA	POSITIVE	-	-	-
		Opportunity for wealth creation	POSITIVE	NA	POSITIVE	-	-	-
		Opportunity for Corporate Social Responsibility	POSITIVE	NA	POSITIVE	-	-	-
		Exposure to radioactive materials	HIGH	<ul style="list-style-type: none"> SPDC shall ensure that only certified personnel handle radioactive materials. SPDC shall ensure that radioactive materials are stored safely. SPDC shall ensure toolbox talks are conducted before the commencement of the job. SPDC shall ensure appropriate PPEs are used by the workers 	LOW	Certification of workforce Emergency response plan HAZID register Pep-talk records	Monthly During activities involving radioactive materials – welding, NDT	SPDC: Central Hub Asset Manager Regulators; FMEnv, DPR and all Relevant state and Federal Environmental Regulatory bodies
		Third party agitation	HIGH	<ul style="list-style-type: none"> SPDC shall enlighten its contractors and project personnel prior to deployment on proper conduct within stakeholder communities SPDC shall maintain effective liaison/communication with communities and ensure the community cultural profile is not infringed. 	LOW	Minutes of consultation sessions Evidence of GMoU agreement and implementation	Monthly	Central Hub Asset Manager

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						Site reports on how disputes were settled		
		Potential attack from wild/predatory animals (Snakes, Scorpions)	HIGH	SPDC shall <ul style="list-style-type: none"> ▪ SPDC shall ensure that waste generated from the project during the period of construction are managed from cradle to grave. ▪ The site clinic shall stock anti-snake bite venom ▪ Awareness shall be created among workers on the possibility of exposure to poisonous wildlife ▪ Ensure adequate Medivac system and on site referral system. 	LOW	Inspection records Site incident report	Monthly	SPDC: Central Hub Asset Manager Regulators; FMEEnv, DPR and all Relevant state and Federal Environmental Regulatory bodies
		Increase in exposure to transborder diseases (Zika virus, Ebola, Birdflu, SARS), Antimicrobial resistant bacteria	HIGH	<ul style="list-style-type: none"> ▪ SPDC shall ensure that Expatriate staff pass through proper immigration Health checks before arriving at the worksite. ▪ SPDC shall ensure Health education is part of orientation for all foreign staff. ▪ Fitness-to-Work protocol must be adhered strictly to and Implemented by site supervisors and OHNs. 	LOW	Inspection records Site incident report	Monthly	SPDC: Central Hub Asset Manager Regulators; FMEEnv, DPR and all Relevant state and Federal Environmental Regulatory bodies
		Crime and insecurity (Kidnapping, Hostage-taking, armed robbery, Militancy)	HIGH	SPDC shall <ul style="list-style-type: none"> • advise the contractors to site recruitment office away from the work site to reduce job seekers at the site • SPDC shall ensure access control is implemented at work site. • SPDC shall implement proper journey management system. 	LOW	<ul style="list-style-type: none"> • Evidence of stakeholders engagements • Records of security incidences • Project security plan 	Monthly	Central Hub Asset Manager

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				<ul style="list-style-type: none"> Work with the Government, communities and other relevant agencies to improve security in the project area. ensure that security orientation and awareness is conducted for workforce. Work with the Government, communities and other relevant agencies to improve security in the project area ensure that security orientation and awareness is conducted for workforce. 		<ul style="list-style-type: none"> Record of security orientation and awareness 		
		Access to hunting grounds	MEDIUM	Establishment of agricultural extension services and empowerment scheme.	LOW	Site Inspection records	Annually	SPDC: Central Hub Asset Manager Regulators; FMEEnv, DPR and all Relevant state and Federal Environmental Regulatory bodies
		Potential reduction in household water quality and contamination of potable water	HIGH	<ul style="list-style-type: none"> SPDC shall provide water for their staff in the camps during construction and operations. Large proportion of the semi-skilled and un-skilled labours shall be sourced from the communities to reduce migrant workers. Staff recruitment shall be done outside the communities for skilled labours not excluding the members of the communities. 	LOW	Site Inspection records	Annually	Central Hub Asset Manager
		Temporary disruption of local fishing/harvesting activities.	MEDIUM	SPDC shall ensure strict compliance with good marine journey management practice, including sensitization of quarter masters / boat masters on how to pass fishing and commercial boat	LOW	<ul style="list-style-type: none"> Pre-mob certificates Maintenance records 	Quarterly	SPDC: Central Hub Asset Manager Regulators; FMEEnv, DPR and all Relevant state and Federal Environmental Regulatory bodies

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						<ul style="list-style-type: none"> Evidence of issuance of PPEs 		
		Acidification of the soil and surface water as a result of deposition of dredge spoils on the banks of the river	MEDIUM	SPDC shall ensure dredge spoil is deposited at least 10 metres into the buffer zone or Cap spoil with clean sand.	LOW	Site Inspection records Environmental Compliance monitoring	Quarterly	SPDC: Central Hub Asset Manager Regulators; FMEnv, DPR and all Relevant state and Federal Environmental Regulatory bodies
		Spoil disposal will smother epifauna and impair surface drainage especially in wetland areas	MEDIUM	SPDC shall dispose dredge spoils in an environmentally-friendly manner	LOW	Site Inspection records Environmental Compliance monitoring	Quarterly	SPDC: Central Hub Asset Manager Regulators; FMEnv, DPR and all Relevant state and Federal Environmental Regulatory bodies
		Disaggregation of benthic habitats and loss of benthic organisms.	MEDIUM	SPDC shall adopt due diligence to minimize adverse impacts on benthic organisms	LOW	Site Inspection records Environmental Compliance monitoring	Quarterly	SPDC: Central Hub Asset Manager Regulators; FMEnv, DPR and all Relevant state and Federal Environmental Regulatory bodies Manager
		Disturbance of riverbed topography and re-suspension of fine sediments and bottom materials	MEDIUM	SPDC shall ensure minimal disturbance to the river bed during pipeline crossing.	LOW	Site Inspection records	Quarterly	SPDC: Central Hub Asset Manager Regulators; FMEnv, DPR and all Relevant state and Federal Environmental Regulatory bodies

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		Disturbance of riverbed topography	MEDIUM	SPDC shall ensure minimal disturbance to the river bed during pipeline crossing.	LOW	Site Inspection records	Quarterly	SPDC: Central Hub Asset Manager Regulators; FMEEnv, DPR and all Relevant state and Federal Environmental Regulatory bodies Manager
	Drilling and well hook-up	Increase in noise & vibration nuisance	HIGH	<ul style="list-style-type: none"> SPDC shall provide PPEs (ear muffs, eye goggles) for drilling staff. Where possible SPDC shall provide acoustic enclosure for noisy equipment. First Aid boxes shall be provided at the drilling site and trained First Aiders remain part of the workforce. 	LOW	Site Inspection records	Weekly	Central Hub SPDC: Central Hub Asset Manager Regulators; FMEEnv, DPR and all Relevant state and Federal Environmental Regulatory bodies
		Increase in light nuisance	HIGH	<ul style="list-style-type: none"> Construction activities requiring continuous light at night shall be reduced to the barest minimum. Construction activities shall be completed on schedule 	LOW	<ul style="list-style-type: none"> Pre-mob certificates Maintenance records Evidence of issuance of PPEs 	Monthly	SPDC: Central Hub Asset Manager Regulators; FMEEnv, DPR and all Relevant state and Federal Environmental Regulatory bodies
		Generation of drilling waste	HIGH	<ul style="list-style-type: none"> SPDC shall ensure that high G-shakers are used to reduce the amount of mud in drill cuttings. Recovered drilling mud shall be stored in containers for re-use. Where feasible cuttings re-injection shall be utilized 	LOW	Site Inspection records	Monthly	SPDC: Central Hub Asset Manager Regulators; FMEEnv, DPR and all Relevant state and Federal Environmental Regulatory bodies
		Contamination of environment (soils/surface and groundwater)	HIGH	<ul style="list-style-type: none"> All generated wastes shall be managed in accordance with the provisions of the SPDC Waste Management Guidelines. Where contamination occurs SPDC shall clean up and remediate as appropriate. 	LOW	Waste consignment note Environmental Compliance	Quarterly	SPDC: Central Hub Asset Manager Regulators; FMEEnv, DPR and all Relevant state and Federal Environmental Regulatory bodies

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						monitoring report		
		Work related injury/fatality of workforce	HIGH	<ul style="list-style-type: none"> Workers shall use appropriate PPEs (life jackets, work vests/ goggles etc) SPDC shall ensure first aid box on site and emergency response and med-rescue/medevac are in place. Toolbox meetings shall be held before the start of daily tasks Awareness shall be created among site workers on the likelihood of exposure to poisonous wildlife & plants. Trained First Aiders shall form part of the workforce. SPDC policy on road and water borne traffic journey management shall be adhered to (all journey must be approved, no night journeys, speed limits on land and water. 	LOW	Certification of workforce Emergency response plan HAZID register Pep-talk records	Monthly	SPDC: Central Hub Asset Manager Regulators; FMEEnv, DPR and all Relevant state and Federal Environmental Regulatory bodies
		Non work related injury/fatality of workforce	HIGH	<ul style="list-style-type: none"> SPDC shall ensure all the workers at site have a medical fitness to work and are in good physical and mental health. SPDC policy on road and water borne traffic journey management shall be adhered to (all journey must be approved, no night journeys, speed limits on land and water. 	LOW	Certification of workforce Emergency response plan HAZID register Pep-talk records	Monthly	SPDC: Central Hub Asset Manager Regulators; FMEEnv, DPR and all Relevant state and Federal Environmental Regulatory bodies
		Increase in explosion potential (Well blowout)	HIGH	<ul style="list-style-type: none"> Firefighting extinguishers shall be provided at worksites. Emergency response procedures shall be put in place. SPDC shall use the optiwell (bore hole management) 	LOW	Inspection records Site incident report	Quarterly	SPDC: Central Hub Asset Manager Regulators; FMEEnv, DPR and all Relevant state and Federal Environmental Regulatory bodies

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Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact	Parameter for Monitoring	Frequency of Monitoring/ Formal Reporting	Responsible/ Action Party
				process & other industry best practice to drill wells.				
		Increase in diseases STIs, HIV/AIDS	HIGH	<ul style="list-style-type: none"> ▪ Workers shall be encouraged to undergo voluntary counselling and testing in order to know their HIV status and in turn guide behaviour ▪ SPDC shall ensure condoms are provided for workers at the site clinic and distributed to the communities ▪ SPDC shall enforce access control to base camps ▪ SPDC shall enforce Alcohol and drug policy in the camps /worksite as part of culture of health. 	LOW	<p>Medical records</p> <p>Awareness records</p>	Biannually	SPDC: Central Hub Asset Manager Regulators; FMEEnv, DPR and all Relevant state and Federal Environmental Regulatory bodies
		Increase in endemic diseases	HIGH	<ul style="list-style-type: none"> • SPDC shall support existing health facilities upgrade and staff training. • SPDC shall maintain workers in camp and provide access control measure to reduce intermingling with host communities. 	LOW	<p>Medical records</p> <p>Awareness records</p>	Biannually	SPDC: Central Hub Asset Manager Regulators; FMEEnv, DPR and all Relevant state and Federal Environmental Regulatory bodies
		Emergent Infectious diseases resulting from displacement of disease vectors (rodents and monkeys)	HIGH	<ul style="list-style-type: none"> ▪ SPDC shall ensure that waste generated from the project during the period of construction are managed from cradle to grave. ▪ Health education on the consumption of rodents shall be provided by appropriate health authorities. 	LOW	<p>Medical records</p> <p>Awareness records</p>	Biannually	SPDC: Central Hub Asset Manager Regulators; FMEEnv, DPR and all Relevant state and Federal Environmental Regulatory bodies
		Loss of biodiversity	HIGH	<ul style="list-style-type: none"> ▪ Any vegetation cleared in the lay-down area shall be replanted with native species. ▪ SPDC shall ensure that her workforce do not engage in hunting or fishing. ▪ SPDC shall ensure awareness campaigns are conducted for 	LOW	<p>Inspection records</p> <p>Site incident report</p>	Biannually	SPDC: Central Hub Asset Manager Regulators; FMEEnv, DPR and all Relevant state and Federal Environmental Regulatory bodies

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Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact	Parameter for Monitoring	Frequency of Monitoring/ Formal Reporting	Responsible/ Action Party
				the workforce on the need to preserve the environment. <ul style="list-style-type: none"> ▪ Route clearing shall be done in stages to allow mobile fauna escape from the project area. ▪ SPDC shall implement the BAP policy. 				
		Potential for development of infrastructures and economic enhancement	P	NA	POSITIVE	-	-	-
		Increase in road traffic volume & accident potential/injuries	HIGH	<ul style="list-style-type: none"> • SPDC policy on road and water borne traffic journey management shall be adhered to (all journey must be approved, no night journeys, speed limits on land and water • SPDC shall upgrade existing roads to suite the anticipated project activities and additional access road provided, where necessary 	LOW	<ul style="list-style-type: none"> • Journey management records • Pre-mob certificates • Pep-talk records • Certificate of defensive driving • Vehicle Monitoring Analysis 	Weekly	SPDC: Central Hub Asset Manager Regulators; FMEnv, DPR and all Relevant state and Federal Environmental Regulatory bodies
		Tank leaks	HIGH	<ul style="list-style-type: none"> • All Liquid containers shall be placed in leak-proof bonded concrete housing with proper ventilation. • SPDC shall ensure only certified personnel are allowed to carry-out fuel bunkering / transfer. • The storage shall be properly marked and condoned off from the general worksite public. 	LOW	Inspection records Site incident report	Biannually	SPDC: Central Hub Asset Manager Regulators; FMEnv, DPR and all Relevant state and Federal Environmental Regulatory bodies
		Influx of insect pests	HIGH	<ul style="list-style-type: none"> ▪ SPDC shall carryout health education programmes on the 	LOW	Inspection records	Annually	SPDC: Central Hub Asset Manager

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Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact	Parameter for Monitoring	Frequency of Monitoring/ Formal Reporting	Responsible/ Action Party
				<ul style="list-style-type: none"> Rollback Malaria interventions. Ensure adequate referral system 		Site incident report		Regulators; FMEEnv, DPR and all Relevant state and Federal Environmental Regulatory bodies
		Opportunity for direct and indirect Employment (Unskilled labour)	P	NA	POSITIVE	-	-	-
		Opportunity for wealth creation	P	NA	POSITIVE	-	-	-
		Opportunity for Corporate Social Responsibility	P	NA	POSITIVE	-	-	-
		Gender imbalance	HIGH	<ul style="list-style-type: none"> SPDC shall enforce existing laws against gender-based employment discrimination and against sexual harassment. SPDC shall Increase mentorship and other efforts to boost the number of women in traditionally male occupations. 	LOW	Community engagement sessions	Annually	SPDC: Central Hub Asset Manager Regulators; FMEEnv, DPR and all Relevant state and Federal Environmental Regulatory bodies
		Potential for skills acquisition	P	NA	P	-	-	-
		Pressure on existing infrastructure and services (Water, Electricity, Recreational facilities, Health facilities, Roads and others)	HIGH	<ul style="list-style-type: none"> SPDC shall advise the contractor to locate recruitment office away from the work site to reduce job seekers at the site Workers camps shall be provided for the workforce by the Contractor to reduce the pressure on housing. SPDC shall ensure access control is implemented at work site Patronage of commercial sex workers by workforce shall be discouraged through health awareness campaigns to be conducted by SPDC. SPDC shall ensure unskilled and where feasible semi- 	LOW	Site inspection report	Biannually	SPDC: Central Hub Asset Manager Regulators; FMEEnv, DPR and all Relevant state and Federal Environmental Regulatory bodies

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Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact	Parameter for Monitoring	Frequency of Monitoring/ Formal Reporting	Responsible/ Action Party
				skilled workers are sourced from immediate communities. <ul style="list-style-type: none"> SPDC and contractor shall provide for health care needs of workforce outside of those in the community. Construction should be done in phases so as to reduce the number of workers at site in any particular time. 				
		Third party agitation	HIGH	<ul style="list-style-type: none"> SPDC shall implement the PGMOU in line with agreed template. SPDC shall enlighten its contractors and project personnel prior to deployment on proper conduct within stakeholder communities and maintain effective liaison/communication with communities and ensure the community's economic and cultural profiles are not infringed. 	LOW	Employment records Community Engagement reports	Biannually	SPDC: Central Hub Asset Manager Regulators; FMEEnv, DPR and all Relevant state and Federal Environmental Regulatory bodies
		Attack from wild/predatory animals (Snakes, Scorpions)	HIGH	<ul style="list-style-type: none"> SPDC shall ensure that waste generated from the project during the period of construction are managed from cradle to grave. The site clinic shall stock anti-snake bite venom Awareness shall be created among workers on the possibility of exposure to poisonous wildlife Ensure adequate Medivac system and on site referral system. 	LOW	Site Incident report Emergency response plan HAZID register Pep-talk records	Biannually	SPDC: Central Hub Asset Manager Regulators; FMEEnv, DPR and all Relevant state and Federal Environmental Regulatory bodies
		Exposure to radioactive materials	HIGH	<ul style="list-style-type: none"> SPDC shall ensure that only certified personnel handle radioactive materials. 	LOW	Certification of workforce	Quarterly	SPDC: Central Hub Asset Manager Regulators; FMEEnv, DPR and all Relevant

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Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact	Parameter for Monitoring	Frequency of Monitoring/ Formal Reporting	Responsible/ Action Party
				<ul style="list-style-type: none"> ▪ SPDC shall ensure that radioactive materials are stored safely. ▪ SPDC shall ensure toolbox talks are conducted before the commencement of the job ▪ SPDC shall ensure appropriate PPEs are used by the workers 		Emergency response plan HAZID register Pep-talk records		state and Federal Environmental Regulatory bodies
		Crime and insecurity (Kidnapping, Hostage-taking, armed robbery, Militancy)	HIGH	<ul style="list-style-type: none"> • SPDC shall advise the contractor to site recruitment office away from the work site to reduce job seekers at the site. • SPDC shall ensure access control is implemented at work site • SPDC shall implement proper journey management system. • SPDC shall work with the Government, communities and other relevant agencies to improve security in the project area • SPDC shall ensure that security orientation and awareness is conducted for workforce. • SPDC shall ensure that security orientation and awareness is conducted for workforce. 	MEDIUM	<ul style="list-style-type: none"> • Evidence of stakeholders engagements • Records of security incidences • Project security plan • Record of security orientation and awareness 	Monthly	SPDC: Central Hub Asset Manager Regulators; FMEEnv, DPR and all Relevant state and Federal Environmental Regulatory bodies
	Well & pipeline testing, Hydrotesting,	Potential for explosion	HIGH	<ul style="list-style-type: none"> • Firefighting extinguishers shall be provided at worksites. • Emergency response procedures shall be put in place 	LOW	Certification of workforce Emergency response plan HAZID register Pep-talk records	Quarterly	SPDC: Central Hub Asset Manager Regulators; FMEEnv, DPR and all Relevant state and Federal Environmental Regulatory bodies

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Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact	Parameter for Monitoring	Frequency of Monitoring/ Formal Reporting	Responsible/ Action Party
		Discharge of untreated test water into the receiving environment	MEDIUM	SPDC waste management specifications and guidelines (especially with regards to the discharges into the environment) shall be complied with.	LOW	Inspection records Site incident report	Quarterly	Central Hub Asset Manager
	Cathodic Protection,	Exposure to radioactive material	HIGH	<ul style="list-style-type: none"> SPDC shall ensure that only certified personnel handle radioactive materials. SPDC shall ensure that radioactive materials are stored safely. SPDC shall ensure toolbox talks are conducted before the commencement of the job. SPDC shall ensure appropriate PPEs are used by the workers 	LOW	Certification of workforce Emergency response plan HAZID register Pep-talk records	Quarterly	Central Hub Asset Manager
	Commissioning & Handover	Increase in Business opportunities	P	NA	POSITIVE	-	-	-
		Gas flaring from well tests	HIGH	<ul style="list-style-type: none"> SPDC shall ensure Safety signage shall be deployed at strategic locations. Emergency response plan shall be in place Use of appropriate PPEs provision of adequate firefighting equipment 	LOW	Certification of workforce Emergency response plan HAZID register Pep-talk records	Quarterly	Central Hub Asset Manager
		Increase in noise & vibration nuisance	HIGH	<ul style="list-style-type: none"> Mufflers shall be installed on machineries and low noise generators shall be used. Noise level shall be monitored to ensure safe levels are not exceeded. There shall be no night work Noise in the communities shall be measured every three months 	LOW	<ul style="list-style-type: none"> Pre-mob certificates Maintenance records Evidence of issuance of PPEs Site inspection reports 	Weekly	Central Hub Asset Manager

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Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact	Parameter for Monitoring	Frequency of Monitoring/ Formal Reporting	Responsible/ Action Party
						Environmental compliance monitoring report		
		Generation of waste (Pigging waste, domestic waste, metal scraps, plastics)	HIGH	<ul style="list-style-type: none"> ▪ SPDC and contractors shall ensure that all wastes are segregated and managed according to EGASPIN and FMEnv guidelines. ▪ Enforce access control to ensure that wastes are not indiscriminately transferred from one place to the other by members of the communities in the act of picking properties. ▪ Ensure proper documentation of the quantity of waste from generated site to disposal point 	LOW	Waste consignment note Monitoring of recipient environment in line with EGASPIN 2002	Monthly	Central Hub Asset Manager
		Contamination of environment (soils/surface and groundwater)	HIGH	<ul style="list-style-type: none"> • Waste management plans (in line with regulatory guidelines and SPDC procedures) shall be strictly adhered to during all phases of the project. • Wastes shall be segregated at source into color-coded or labelled bins and disposed of in line with a project specific waste management plan. • SPDC shall ensure that sewage wastes in base camps are properly managed. • Safe Handling of Chemicals (SHOC) cards shall be visibly displayed at all sites where chemicals are handled • Fuel, lube oils and chemicals shall be safely stored in containers in bonded areas 	LOW	Waste consignment note Monitoring of recipient environment in line with EGASPIN 2002	Quarterly	Central Hub Asset Manager

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Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact	Parameter for Monitoring	Frequency of Monitoring/ Formal Reporting	Responsible/ Action Party
		Work related injury/fatality of workforce	HIGH	<ul style="list-style-type: none"> ▪ Workers shall use appropriate PPEs (life jackets, work vests/ goggles etc) ▪ SPDC shall ensure first aid box on site and emergency response and medevac are in place ▪ Toolbox meetings shall be held before the start of daily tasks ▪ Awareness shall be created among site workers on the likelihood of exposure to poisonous wildlife & plants ▪ Trained First Aiders shall form part of the workforce in the ratio of 1:25 ▪ Ensure adequate MEDEVAC and referral system 	LOW	Certification of workforce Emergency response plan HAZID register Pep-talk records	Monthly	Central Hub Asset Manager
		Non work related injury/fatality of workforce	HIGH	<ul style="list-style-type: none"> • SPDC shall ensure every worker have a medical certificate of fitness to work. • SPDC shall ensure that workers suffering from terminal diseases are not accommodate in camp. • SPDC shall ensure that a trained medic is assigned to the site camp. 	LOW	Certification of workforce Emergency response plan HAZID register Pep-talk records	Monthly	Central Hub Asset Manager
		Increase in explosion potential	HIGH	<ul style="list-style-type: none"> • Firefighting extinguishers shall be provided at worksites • Emergency response procedures shall be put in place. • SPDC shall use the optiwell (bore hole management) process & other industry best practice to drill her wells 	LOW	Certification of workforce Emergency response plan HAZID register Pep-talk records	Quarterly	Central Hub Asset Manager

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Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact	Parameter for Monitoring	Frequency of Monitoring/ Formal Reporting	Responsible/ Action Party
		Increase in diseases STIs, HIV/AIDS	HIGH	<ul style="list-style-type: none"> ▪ Workers shall be encouraged to undergo voluntary counselling and testing in order to know their HIV status and in turn guide behaviour ▪ SPDC shall enforce access control to base camps ▪ SPDC shall enforce Alcohol and drug policy in the camps /worksite as part of culture of health. 	LOW	<p>Medical records</p> <p>Awareness records</p>	Monthly	Central Hub Asset Manager
		Increase in endemic diseases (Malaria, Typhoid, RTI)	HIGH	<ul style="list-style-type: none"> ▪ Carryout health education on the Rollback Malaria interventions. ▪ Ensure adequate referral system 	LOW	<p>Medical records</p> <p>Awareness records</p>	Monthly	Central Hub Asset Manager
		Development of infrastructures and economic enhancement (GMoU)	P	NA	POSITIVE	-	-	-
		Increase in road traffic volume & accident potential/injuries	HIGH	<ul style="list-style-type: none"> • SPDC shall ensure all vehicles are pre-mobbed and certified. • Visible warning signs shall be placed on roads and vehicle. • SPDC shall ensure all drivers undergo the defensive driving course and are certified. • Vehicle monitoring and communication devices shall be installed in project vehicles. • SPDC shall ensure journey management and 'no night driving policy' shall be adhered to. • SPDC shall ensure compulsory medical fitness test for all drivers 	LOW	<p>Site inspection/ stakeholder engagement reports IVMS checks/Reports</p> <p>Inventory of approved journey management forms</p>	Quarterly	Central Hub Asset Manager
		Tank leaks	HIGH	<ul style="list-style-type: none"> • All Liquid containers shall be placed in leak-proof bonded concrete housing with proper ventilation. 	LOW	Site inspection report	Quarterly	Central Hub Asset Manager

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				<ul style="list-style-type: none"> SPDC shall ensure only certified personnel are allowed to carry-out fuel bunkering / transfer. The storage shall be properly marked and condoned off from the general worksite public. 				
		Opportunity for direct and indirect Employment (Unskilled labour)	P	NA	POSITIVE	-	-	-
		Opportunity for wealth creation	P	NA	POSITIVE	-	-	-
		Loss of Employment (local labour) (Boom burst cycle)	HIGH	SPDC shall as long as reasonably possible ensure the engagement of community members when actual production begins	LOW	Community Engagement reports	Biannually	Central Hub Asset Manager
		Third party agitation	HIGH	<ul style="list-style-type: none"> SPDC shall implement the GMoU in line with agreed template. SPDC shall enlighten its contractors and project personnel prior to deployment on proper conduct within stakeholder communities and maintain effective liaison/communication with communities and ensure the community's economic and cultural profiles are not infringed. 	LOW	Employment records Community Engagement reports	Biannually	Central Hub Asset Manager
		Attack from wild animals (Snakes, Scorpions)	HIGH	<ul style="list-style-type: none"> SPDC shall ensure that waste generated from the project during the period of construction are managed from cradle to grave. Health education on the consumption of rodents shall be provided by appropriate health authorities The site clinic shall stock anti-snake bite venom 	LOW	Inspection records Site incident report	Biannually	Central Hub Asset Manager

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				<ul style="list-style-type: none"> Awareness shall be created among workers on the possibility of exposure to poisonous wildlife Ensure adequate Medivac system and on site referral system. 				
		Crime and insecurity (Kidnapping, Hostage-taking, armed robbery, Militancy)	HIGH	<ul style="list-style-type: none"> SPDC shall advise the contractor to site recruitment office away from the work site to reduce job seekers at the site. SPDC shall ensure access control is implemented at work site SPDC shall implement proper journey management system. SPDC shall work with the Government, communities and other relevant agencies to improve security in the project area SPDC shall ensure that security orientation and awareness is conducted for workforce. SPDC shall ensure that security orientation and awareness is conducted for workforce. 	MEDIUM	<ul style="list-style-type: none"> Evidence of stakeholders engagements Records of security incidences Project security plan Record of security orientation and awareness 	Monthly	Central Hub Asset Manager
		Increased exposure to carcinogenic substances	HIGH	<ul style="list-style-type: none"> SPDC shall carryout awareness campaign in educating the communities members to keep the required distance when rays are being used for welding joints and other radioactive services. SPDC shall ensure that the emergency contingencies are in place to address any spill to minimise contamination of food and water sources. 	LOW	<ul style="list-style-type: none"> Medical records Awareness records Site incident report HAZID register Pep-talk records 	Quarterly	Central Hub Asset Manager

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Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact	Parameter for Monitoring	Frequency of Monitoring/ Formal Reporting	Responsible/ Action Party
		Alcohol and drug abuse	HIGH	<ul style="list-style-type: none"> Ensure the implementation of the company's alcohol and drug policies Pre-activity health/sex education campaign shall be conducted for both workforce and communities. 	LOW	Reports on community engagement sessions Site inspection report/tool box meetings	Quarterly	Central Hub Asset Manager
Demobilization		Increase in road traffic, potential for accidents and injuries	HIGH	<ul style="list-style-type: none"> Visible warning signs shall be placed at strategic positions along the roads. SPDC shall ensure there is traffic control at strategic points along the road. SPDC shall ensure all vehicles observe the speed limits and large vehicles have warning lights to alert other road users. SPDC shall ensure all project vehicles are pre-mobbed and certified 	LOW	Site inspection/ stakeholder engagement reports IVMS checks/Reports Inventory of approved journey management forms	Quarterly	Central Hub Asset Manager
		Damage to road infrastructure	HIGH	SPDC shall built roads to its location where they do not exist and maintain existing roads to its location without refusing the general public from using same.	LOW	Site inspection Inventory of approved Journey Management forms	Quarterly	Central Hub Asset Manager
		Impairment in air quality	HIGH	<ul style="list-style-type: none"> SPDC shall wet the site before excavation and construction to minimize dust. Health advise to the communities members (particularly the under aged) to stay away from construction site Access control to the project area should enforced Health education shall be delivered to the communities 	LOW	<ul style="list-style-type: none"> Pre-mob certificates Vehicle Maintenance records 	Weekly	Central Hub Asset Manager

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Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact	Parameter for Monitoring	Frequency of Monitoring/ Formal Reporting	Responsible/ Action Party
				members on the need to dependence on the use of firewood due to negative health effect.				
		Increase in noise and vibration	HIGH	<ul style="list-style-type: none"> ▪ Mufflers shall be installed on machineries and low noise generators shall be used. ▪ Noise level shall be monitored to ensure safe levels are not exceeded. ▪ There shall be no night work ▪ Noise in the communities shall be measured every three months 	LOW	<ul style="list-style-type: none"> • Pre-mob certificates • Maintenance records • Evidence of issuance of PPEs • Site inspection reports 	Weekly	Central Hub Asset Manager
		Increase in refined hydrocarbon contents of soil and vegetation	HIGH	<ul style="list-style-type: none"> • SPDC shall ensure fuel bunkering is done within stipulated bonded area that is leak proof to avoid contamination. • Service vehicles regularly to reduce emissions from exhaust. • Vehicles should fuel and refuel at designated stations. 	LOW	<ul style="list-style-type: none"> • Pre-mob certificates • Maintenance records • Evidence of issuance of PPEs • Site inspection reports 	Monthly	Central Hub Asset Manager
		Increase in crime rate	HIGH	<ul style="list-style-type: none"> • SPDC shall advise the contractor to site recruitment office away from the work site to reduce job seekers at the site. • SPDC shall ensure access control is implemented at work site • SPDC shall implement proper journey management system. • SPDC shall work with the Government, communities and other relevant agencies to improve security in the project area • SPDC shall ensure that security orientation and awareness is conducted for workforce. 	MEDIUM	<ul style="list-style-type: none"> • Evidence of stakeholders engagements • Records of security incidences • Project security plan • Record of security orientation and awareness 	Monthly	Central Hub Asset Manager

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				<ul style="list-style-type: none"> SPDC shall ensure that security orientation and awareness is conducted for workforce. 				
		Soil compaction	LOW	<ul style="list-style-type: none"> SPDC shall ensure that there is restriction to permanent wheel tracks. SPDC shall ensure trucks avoid waterlogged routes. 	LOW	<ul style="list-style-type: none"> Site inspection reports 	Quarterly	Central Hub Asset Manager
		Waste generation (Scrap metals, Woods, Food waste)	HIGH	<ul style="list-style-type: none"> Waste management plans (in line with regulatory guidelines and SPDC procedures) shall be strictly adhered to during all phases of the project. Wastes shall be segregated at source into color-coded or labelled bins and disposed of in line with a project specific waste management plan 	LOW	Waste consignment note Monitoring of recipient environment in line with EGASPIN 2002	Monthly	Central Hub Asset Manager
		Opportunity for contracting	P	NA	POSITIVE	-	-	-
		Opportunity for direct and indirect Employment (Unskilled labour)	P	NA	POSITIVE	-	-	-
		Loss of Employment (local labour)	HIGH	SPDC shall <ul style="list-style-type: none"> support entrepreneurial skill development and opportunities for community members to cushion the effect of reduction in economic/income generating activities. 	LOW	Contractor engagement report, employment records	Quarterly	Central Hub Asset Manager
		Third party agitation	HIGH	<ul style="list-style-type: none"> SPDC shall discuss and agree on sustainable community development project and implement agreed projects, these will serve the whole fence line communities without bias. SPDC shall sign and implement GMoU with communities; 	LOW	Employment records Community Engagement reports	Quarterly	Central Hub Asset Manager

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				<ul style="list-style-type: none"> SPDC shall sustain stakeholders engagement throughout the project lifecycle. SPDC shall ensure Infrastructural development via GMoU implementation 				
		Crime and insecurity (Kidnapping, Hostage-taking, armed robbery, Militancy)	HIGH	<ul style="list-style-type: none"> SPDC shall advise the contractor to site recruitment office away from the work site to reduce job seekers at the site. SPDC shall ensure access control is implemented at work site SPDC shall implement proper journey management system. SPDC shall work with the Government, communities and other relevant agencies to improve security in the project area SPDC shall ensure that security orientation and awareness is conducted for workforce. SPDC shall ensure that security orientation and awareness is conducted for workforce. 	MEDIUM	<ul style="list-style-type: none"> Evidence of stakeholders engagements Records of security incidences Project security plan Record of security orientation and awareness 	Monthly	Central Hub Asset Manager
		Increase in RTIs due to dust particles	HIGH	<ul style="list-style-type: none"> SPDC shall wet the site before excavation and construction to minimize dust. Health advise to the communities members (particularly the under aged) to stay away from construction site Access control to the project area should enforced 	LOW	Medical records Awareness records	Biannually	Central Hub Asset Manager
		Social dislocation	HIGH	<ul style="list-style-type: none"> SPDC shall advise the contractor to site recruitment office away from the project 	LOW	Stakeholders engagement sessions	Biannually	Central Hub Asset Manager

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				site to reduce job seekers at the site. <ul style="list-style-type: none"> • SPDC shall ensure access control is implemented at work site. • SPDC shall ensure health awareness campaigns are conducted for workforce on the risks of STIs from the services of CSWs to discourage patronage 				
		Increased exposure to carcinogenic substances	HIGH	<ul style="list-style-type: none"> • SPDC shall ensure that only certified personnel handle radioactive materials. • SPDC shall ensure that radioactive materials are stored safely. • SPDC shall ensure toolbox talks are conducted before the commencement of the job • SPDC shall ensure appropriate PPEs are used by the workers 	LOW	Medical records Awareness records Site incident report HAZID register Pep-talk records	Biannually	Central Hub Asset Manager
		Alcohol and drug abuse	HIGH	<ul style="list-style-type: none"> ▪ Ensure the implementation of the company's alcohol and drug policies. ▪ Carryout awareness campaign on alcohol and drug abuse in schools, churches and town halls to reduce alcohol intake in the communities. ▪ Pre-activity health/sex education campaign shall be conducted for both workforce and communities. 	LOW	Reports on community engagement sessions Site inspection report/tool box meetings	Biannually	Central Hub Asset Manager
Operation	Well work-over, Gas production,	Potential for environmental contamination due to gas leaks	HIGH	SPDC shall ensure <ul style="list-style-type: none"> • Safety signage shall be deployed at strategic locations. • Emergency response plan shall be in place 	LOW	Certification of workforce Emergency response plan	Monthly	Central Hub Asset Manager

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				<ul style="list-style-type: none"> Use of appropriate PPEs provision of adequate firefighting equipment 		HAZID register Pep-talk records		
	Pipeline maintenance & replacement	Increase in business opportunities	POSITIVE	NA	POSITIVE	-	-	-
		Increase in potential for injury/fatality of workforce & third parties	HIGH	<ul style="list-style-type: none"> Workers shall use appropriate PPEs (life jackets, work vests/ goggles etc) SPDC shall ensure first aid box on site and emergency response and medevac are in place Toolbox meetings shall be held before the start of daily tasks Awareness shall be created among site workers on the likelihood of exposure to poisonous wildlife & plants Trained First Aiders shall form part of the workforce in the ratio of 1:25 Ensure adequate MEDEVAC and referral system 	LOW	Certification of workforce Emergency response plan HAZID register Pep-talk records	Monthly	Central Hub Asset Manager
		Revenue generation for government and SPDC	POSITIVE	NA	POSITIVE	-	-	-
		Increase in potential for sabotage of facilities	HIGH	SPDC shall <ul style="list-style-type: none"> Develop and implement a security management plan for the project Ensure routine surveillance of facility 	LOW	<ul style="list-style-type: none"> Evidence of stakeholders engagements Records of security incidences Project security plan Record of security 	Monthly	Central Hub Asset Manager

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						orientation and awareness		
		Reduction in gas flaring	POSITIVE	NA	POSITIVE	-	-	-
		Increase in diseases STIs HIV/AIDS	HIGH	<ul style="list-style-type: none"> Workers shall be encouraged to undergo voluntary counselling and testing in order to know their HIV status and in turn guide behaviour SPDC shall ensure condoms are provided for workers at the site clinic and distributed to the communities. SPDC shall enforce access control to base camps SPDC shall enforce Alcohol and drug policy in the camps /worksites as part of culture of health. 	LOW	Medical records Access Control/ID card Awareness records	Monthly	Central Hub Asset Manager
		Prevalence in endemic diseases (Malaria, Typhoid, RTI)	HIGH	<ul style="list-style-type: none"> Carryout health education on the Rollback Malaria interventions. Ensure adequate referral system 	LOW	Medical records Awareness records	Biannually	Central Hub Asset Manager
		Opportunity for contracting	POSITIVE	NA	POSITIVE	-	-	-
		Opportunity for direct and indirect Employment (Unskilled labour)	POSITIVE	NA	POSITIVE	-	-	-
		Third party agitation	HIGH	<ul style="list-style-type: none"> SPDC shall discuss and agree on sustainable community development project and implement agreed projects, these will serve the whole fence line communities without bias. 	LOW	Minutes of consultation sessions Evidence of GMoU agreement and implementation	Biannually	Central Hub Asset Manager

Environmental Impact Assessment of Enwhe Field Development Project – Final Report

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact	Parameter for Monitoring	Frequency of Monitoring/ Formal Reporting	Responsible/ Action Party
				<ul style="list-style-type: none"> SPDC shall sign and implement GMoU with communities; SPDC shall sustain stakeholders engagement throughout the project lifecycle. SPDC shall ensure Infrastructural development via PGMoU implementation 		Site reports on how disputes were settled		
		Crime and insecurity (Kidnapping, Hostage-taking, armed robbery, Militancy) and other social vices	HIGH	<ul style="list-style-type: none"> SPDC shall advise the contractor to site recruitment office away from the work site to reduce job seekers at the site. SPDC shall ensure access control is implemented at work site SPDC shall implement proper journey management system. SPDC shall work with the Government, communities and other relevant agencies to improve security in the project area SPDC shall ensure that security orientation and awareness is conducted for workforce. SPDC shall ensure that security orientation and awareness is conducted for workforce. 	LOW	<ul style="list-style-type: none"> Evidence of stakeholders engagements Records of security incidences Project security plan Record of security orientation and awareness 	Quarterly	Central Hub Asset Manager
		Waste generation (Scrap metals, Woods, Food waste)	HIGH	<ul style="list-style-type: none"> Waste management plans (in line with regulatory guidelines and SPDC procedures) shall be strictly adhered to during all phases of the project. Wastes shall be segregated at source into color-coded or labelled bins and disposed of in line with a project specific waste management plan. 	LOW	Waste consignment note Monitoring of recipient environment in line with EGASPIN 2002	Monthly	Central Hub Asset Manager

Environmental Impact Assessment of Enwhe Field Development Project – Final Report

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact	Parameter for Monitoring	Frequency of Monitoring/ Formal Reporting	Responsible/ Action Party
		Increased exposure to carcinogenic substances	HIGH	<ul style="list-style-type: none"> • SPDC shall ensure that only certified personnel handle radioactive materials. • SPDC shall ensure that radioactive materials are stored safely. • SPDC shall ensure toolbox talks are conducted before the commencement of the job • SPDC shall ensure appropriate PPEs are used by the workers 	LOW	Medical records Awareness records Site incident report HAZID register Pep-talk records	Quarterly	Central Hub Asset Manager
		Alcohol and drug abuse	HIGH	<ul style="list-style-type: none"> ▪ Ensure the implementation of the company's alcohol and drug policies. ▪ Carryout awareness campaign on alcohol and drug abuse in schools, churches and town halls to reduce alcohol intake in the communities. ▪ Pre-activity health/sex education campaign shall be conducted for both workforce and communities. 	LOW	Reports on community engagement sessions Site inspection report/tool box meetings	Biannually	Central Hub Asset Manager
		Contamination of surface water/Sediment	HIGH	<ul style="list-style-type: none"> • Waste management plans (in line with regulatory guidelines and SPDC procedures) shall be strictly adhered to during all phases of the project. • Wastes shall be segregated at source into color-coded or labelled bins and disposed of in line with a project specific waste management plan. • SPDC shall ensure that sewage wastes in base camps are properly managed (i.e. using a sewage treatment plant). • Safe Handling of Chemicals (SHOC) cards shall be visibly 	LOW	Waste consignment note Monitoring of recipient environment in line with EGASPIN 2002	Quartely	Central Hub Asset Manager

Environmental Impact Assessment of Enwhe Field Development Project – Final Report

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact	Parameter for Monitoring	Frequency of Monitoring/ Formal Reporting	Responsible/ Action Party
				displayed at all sites where chemicals are handle <ul style="list-style-type: none"> Fuel, lube oils and chemicals shall be safely stored in containers in bonded areas. 				
Decommissioning and abandonment	<ul style="list-style-type: none"> Flushing of pipelines Vacuum drying of pipeline Capping of pipeline Removal of surface installations Plugging of wells Site restoration Return of land to owner(s) 	Increase in potential for soil and water contamination	HIGH	SPDC shall ensure: <ul style="list-style-type: none"> all wastes are properly segregated and contained before disposal all wastes are properly disposed of and monitored from cradle to grave All effluents are treated to regulatory limits before discharge 	LOW	<ul style="list-style-type: none"> Waste consignment note Monitoring of recipient environment in line with EGASPIN 2002 	Quarterly	Central Hub Asset Manager
		Increase in litigation potential	HIGH	<ul style="list-style-type: none"> The relevant stakeholders/legacy issues shall be identified Regular consultation with stakeholders (Govt., Community, NGOs, CBOs etc.) shall be undertaken. Project Advisory Committee (PAC) shall be set up to guide MOU implementation and address issues/concerns 	LOW	Stakeholders engagement session	Biannually	Central Hub Asset Manager
		Loss of job by community surveillance team	HIGH	SPDC shall <ul style="list-style-type: none"> support entrepreneurial skill development and opportunities for community members to cushion the effect of reduction in economic/income generating activities. 	LOW	Contractor engagement report, employment records	Quarterly	Central Hub Asset Manager
		Increase in usable land resource to the community	POSITIVE	NA	POSITIVE	-	-	-
		Opportunity for contracting	POSITIVE	NA	POSITIVE	-	-	-
		Opportunity for direct and indirect Employment (Unskilled labour)	POSITIVE	NA	POSITIVE	-	-	-

Environmental Impact Assessment of Enwhe Field Development Project – Final Report

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact	Parameter for Monitoring	Frequency of Monitoring/ Formal Reporting	Responsible/ Action Party
		Third party agitation	HIGH	<ul style="list-style-type: none"> SPDC shall discuss and agree on sustainable community development project and implement agreed projects, these will serve the whole fence line communities without bias. SPDC shall sign and implement GMoU with communities; SPDC shall sustain stakeholders engagement throughout the project lifecycle. SPDC shall ensure Infrastructural development via GMoU implementation 	LOW	Minutes of consultation sessions Evidence of GMoU agreement and implementation Site reports on how disputes were settled	Quarterly	Central Hub Asset Manager
		Crime and insecurity (Kidnapping, Hostage-taking, armed robbery, Militancy) and other social vices	HIGH	<ul style="list-style-type: none"> SPDC shall advise the contractor to site recruitment office away from the work site to reduce job seekers at the site. SPDC shall ensure access control is implemented at work site SPDC shall implement proper journey management system. SPDC shall work with the Government, communities and other relevant agencies to improve security in the project area SPDC shall ensure that security orientation and awareness is conducted for workforce. SPDC shall ensure that security orientation and awareness is conducted for workforce. 	LOW	<ul style="list-style-type: none"> Evidence of stakeholders engagements Records of security incidences Project security plan Record of security orientation and awareness 	Quarterly	Central Hub Asset Manager
		Waste generation (Scrap metals, Woods, Food waste)	HIGH	<ul style="list-style-type: none"> SPDC and contractors shall ensure that all wastes are segregated and managed according to EGASPIN and FMEEnv guidelines 	LOW	Waste consignment note	Monthly	Central Hub Asset Manager

Environmental Impact Assessment of Enwhe Field Development Project – Final Report

Project phase	Project activity	Description of impact	Cumulative Impact	Mitigation measures	Residual Impact	Parameter for Monitoring	Frequency of Monitoring/ Formal Reporting	Responsible/ Action Party
				<ul style="list-style-type: none"> Enforce access control to ensure that wastes are not indiscriminately transferred from one place to the other by members of the communities in the act of picking properties. Ensure proper documentation of the quantity of waste from generated site to disposal point 		Monitoring of recipient environment in line with EGASPIN 2002		
		Increased exposure to carcinogenic substances	HIGH	<ul style="list-style-type: none"> SPDC shall carryout awareness campaign in educating the communities members to keep the required distance when rays are being used for welding joints and other radioactive services. SPDC shall ensure that the emergency contingencies are in place to address any spill to minimise contamination of food and water sources. 	LOW	Medical records Awareness records Site incident report HAZID register Pep-talk records	Quarterly	Central Hub Asset Manager
		Alcohol and drug abuse	HIGH	<ul style="list-style-type: none"> Ensure the implementation of the company's alcohol and drug policies 	LOW	Reports on community engagement sessions Site inspection report/tool box meetings	Quarterly	Central Hub Asset Manager
		Prevalence of STIs HIV/AIDS	HIGH	<ul style="list-style-type: none"> SPDC shall enforce access control to base camps SPDC shall enforce Alcohol and drug policy in the camps /worksites as part of culture of health. 	LOW	Medical records Awareness records	Quarterly	Central Hub Asset Manager

**CHAPTER EIGHT
REMEDATION PLANS AFTER DECOMMISSIONING**

Remediation/restoration is a process whereby an abandoned site or field is reinstated to its original condition or an acceptable condition for other uses. In line with the regulatory requirement and SPDC policy on remediation, the facility should be restored and re-instated to environmentally acceptable levels defined by DPR and FMEnv prior to return to their original owners. Remediation shall not start until the decommissioning process is completed and SPDC certifies that all contaminants have been removed from the environment. Where vegetation is sparse and consists of mainly grasses and shrubs, natural re-growth of vegetation may be permitted. In all cases the locations shall be left in a state that is suitable for its intended use. All Surface facilities, whether cement, metal, wood, etc., shall be dismantled and removed. The remedial measures for the potential and associated impact of the decommissioning of facilities and Wells, after the Enwhe field development operations are presented in table below:

Project phase	Project activity	Associated and potential impacts	Remedial measures
Access and Location Preparation	Re-open the boundary of the access road (SPDC RoW)	Destruction of farmland along row which have already been reclaimed by the local farmers	SPDC shall ensure operations are limited to the row. The local farmers shall be engaged and consulted prior to re-opening the boundary of the access road
	Bush clearing/scarification of dilapidated road surface	Loss of biodiversity and subsequent increase in forage for wildlife and disturbances to sensitive plants and animals	SPDC shall ensure Decommissioning activities are limited to the required perimeter. <ul style="list-style-type: none"> • Trucks, equipment etc. are maintained at optimal working condition in accordance with operating manual; and • Encourage the use of mufflers on equipment manifold where necessary to filter particulates and thus reduce its emission into the air.

			<ul style="list-style-type: none"> • Maintain fuel combustion engines at optimal operating conditions • Ensure maintenance of vehicles and equipment
	Earthworks including sharp sand or lateritic fill materials	Landscape fragmentation and likely soil erosion problems, storm water run-off and precipitation storage, habitats for vectors and unauthorized waste dump site due to borrow pit excavation for laterite	<ul style="list-style-type: none"> • SPDC shall ensure that the excavated site is approved; the excavation faces shall be filled or battered to ensure long term stability. The appropriate safe slope angles shall be determined by a qualified engineer. • SPDC shall ensure clean-up for pits (borrow/waste pits) before backfilling and/or re-grading works commence. Waste shall be treated according, in line with SPDC/DPR waste management guidelines.
	Hot rolled asphalt surfacing	Potential for working related injuries (e.g. Scare and burns), noise from paving machinery	<p>SPDC shall ensure that:</p> <ul style="list-style-type: none"> • Workers are kitted in their PPEs e.g. Noise mask, safety shoes • Only certified workers will be permitted to handle asphalt • Asphalt will be stored as part of SHOC
Location rehabilitation	Surface (wellhead, stove pipe etc.) retrieval, waste pit removal as well as hole closure at surface	Solid wastes are produced including metals, concrete waste, contaminated soil	Solid wastes are produced including metals, concrete waste, contaminated soil
		Pollution of aquifers and groundwater supplies as a result of improperly plugged wells which can pose safety risks to humans (ground water pollution).	<p>SPDC shall ensure wells are properly plugged to prevent oil migration and subsequent ground water pollution.</p> <ul style="list-style-type: none"> • SPDC shall ensure clean-up for pits (borrow/waste pits) before backfilling. Waste shall be treated in line with SPDC/DPR waste management guidelines
		Waste generation from well facilities	SPDC shall ensure all categories of waste

			generated shall be carefully collected and treated accordingly. • SPDC shall ensure waste management plan is duly followed
Location restoration	Surface location restoration to its original state where possible / re-vegetation and surface re-contouring	<ul style="list-style-type: none"> • Increased gully erosion due to laterite removal from borrow pit for surface restoration • Introduction of alien invasive species during re-vegetation 	<ul style="list-style-type: none"> • SPDC shall ensure that the excavated site is approved; the pit should have vertical walls to prevent gullies. • SPDC shall ensure that indigenous plant species such as identified during the studies are used to encourage resuscitation and sustenance of local ecosystems and associated services
	Hand over	Land agitations /for farmlands and boundary adjustments between the communities due to rivalry on ownership and reclamation of the reclaimed land	SPDC shall ensure constant engagement, consultation and agreements (MoU) with the communities
		Third party agitations (among communities, CBOs, NGOs)	SPDC shall ensure constant engagement, consultation and agreements (MoU) with the communities
		Increased income from land recovery could change lifestyle (alcoholism and drug abuse, violence, low moral levels)	SPDC shall ensure re-orientation and enlightenment campaigns are carried out during consultation.

CHAPTER NINE

CONCLUSION AND RECOMMENDATIONS

The Environmental Impact Assessment Studies of the Enwhe Field Development Project was carried out in accordance with relevant local, national and international regulations. The methodology applied for the study involved field work, laboratory analyses, review of previous reports and current field data within the area. To achieve this objective, a multi-disciplinary approach was adopted in the assessment of the environmental status and sensitivities of the various biophysical components. The Enwhe Field Development Project is an opportunity to sustain gas supply to NLNG and maximize utilization of Gbaran CPF by developing gas and condensate in the Enwhe field. Other positive impacts of the proposed project include but not limited to the following: increase in business opportunities, provide Opportunity for direct and indirect Employment (Unskilled labour) and Opportunity for contracting.

The identified adverse impacts were generally short-term and can be prevented, reduced, ameliorated, or controlled if the recommended mitigation measures are implemented. An Environmental Management Plan and a Monitoring Plan have been developed to ensure that the identified potential impacts are reduced to “as low as reasonably practicable” (ALARP). The EMP should therefore form the basis for the actual project implementation and future monitoring of environmental components. The approval of this EIA report for the execution of the proposed project is hereby recommended.

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APPENDICES
APPENDIX 1a
DPR Approval for the Enwhe FDP ESR

MINISTRY OF PETROLEUM RESOURCES

DEPARTMENT OF PETROLEUM RESOURCES

7 KOFO ABAYOMI STREET, VICTORIA ISLAND LAGOS

P.M.B. No: 12560

Telephone: 2715730, 4611777

Website: www.dprnigeria.com

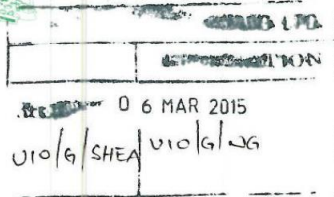


Ref. No: DPR/HSE.02/001.101/2015/013

Date: February 27, 2015

The Managing Director
Shell Petroleum Development Company
Freeman House,
21/22 Marina,
Lagos State.

Dear Sir,



RE: SUBMISSION OF SCREENING REPORTS FOR 3 SPDC PROJECTS; ENWHE FIELD DEVELOPMENT PLAN PROJECT, STRING OF PEARLS HP SWAMP PROJECT, ASSA-NORTH OHAJI SOUTH DETERRENT GAS PIPELINE.

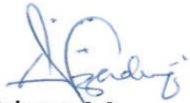
We acknowledge receipt of your letters Ref: UIO/G/NG/SPDC-HSSE-12-2014-024L, UIO/G/NG/SPDC-HSSE-12-2014-027L and UIO/G/NG/SPDC-HSSE-12-2014-029L dated December 12 & 15, 2014 transmitting the Environmental screening reports for the above projects.

2. Following our review of your submission, we wish to convey to you our comments, observations and directives as follows:
 - a. The review of the reports indicates that you have carefully outlined and assessed the various project options and alternatives that were considered prior to narrowing down/zeroing in on the preferred project options.
 - b. Based on the assessment criteria, we concur that the selected project options are best suited for the proposed projects as presented in the report.
3. The above comments in 2 (a & b) notwithstanding, we wish to re-iterate on our expectation with respect to the EIA process. As you are aware, the EGASPIN requires a joint effort between you and the DPR in preparing both the ESR and PIAR. **There is however, room for discretion in managing really small projects and "familiar" environments.** In such cases, in the place of an elaborate technical workshop, basic information about the environmental screening may either be submitted as a separate report, presented during the PIAR workshop or included in the PIAR **if agreeable** to the DPR.
4. At no point did the DPR assent to an independent Environmental Screening exercise for the projects as observed from your submission however, we have decided to overlook this anomaly and

have reviewed the environmental screening reports to enable you progress with the proposed studies. Please note that the DPR will not endorse any reports in future without our participation or assent as statutorily required.

5. You may now proceed to the next phase as required by our EIA process, which is the conduct of a Preliminary Impact Assessment. We expect you to notify us in good time prior to the commencement of this exercise to enable us participate effectively.

Yours faithfully,

A handwritten signature in blue ink, appearing to read 'Balogun A.A.', is written over a faint, light blue grid background.

Balogun A.A.

for: Director of Petroleum Resources

APPENDIX 1b
DPR Approval for the Enwhe FDP ToR/SoW

MINISTRY OF PETROLEUM RESOURCES

DEPARTMENT OF PETROLEUM RESOURCES

7 KOFO ABAYOMI STREET, VICTORIA ISLAND LAGOS...

P.M.B. No: 12560

Telephone: 2715730, 4611777

Website: www.dprnigeria.com



Ref. No: DPR/HSE.02/001.101/2015/041

Date: November 10, 2015

The Managing Director
Shell Petroleum Development Company
Freeman House,
21/22 Marina,
Lagos State.

Dear Sir,

RE: SUBMISSION OF ENVIRONMENTAL SCREENING REPORT, PRELIMINARY IMPACT ASSESSMENT REPORT (PIAR) AND TERMS OF REFERENCE (TOR) FOR THE ENVIRONMENTAL IMPACT ASSESSMENT (EIA) OF PROPOSED SPDC PROJECTS. (ENWHE FIELD DEVELOPMENT PLAN)

We refer to your letter Ref: UIO/G/NG/SPDC-HSSE-10-2015-013L dated October 21, 2015 transmitting the Preliminary impact assessment report (PIAR) & Terms of Reference (TOR) for the Enwhe field development project.

2. We have reviewed the submitted document and wish to observe that the PIAR has met our minimum requirements as agreed in the scoping workshop held on August 11 – 14, 2015. Consequently, we are pleased to convey to you our acquiescence of the Preliminary Impact Assessment for the proposed Enwhe field development project. We have also reviewed the accompanying TOR for the proposed Environmental Impact Assessment study for Enwhe field, which was derived from the PIAR, and wish to convey our approval of same.

3. This approval is premised on the following conditions as proposed in the TOR/SOW:

- i. that relevant environmental samples will be collected based on the proposed positioning of the project development with an in-depth consideration of the environmental sensitivities including any impact receptor within the field.
- ii. that soil & air quality sample locations shall be established in a random and targeted manner to effectively characterise the study area (proposed drilling locations and along the proposed pipeline right of way).
- iii. that surface water and sediment samples will be collected upstream, midstream and downstream of the major water body and streams within the study area.
- iv. that the field data gathering for the study shall be for **two (2) seasons** and the collected samples would be analysed for the following parameters:

S/N	Sample	Sample Type	Analysis	Parameters
1	Soil 63 + 2 control Soil samples shall cover the proposed Wells locations, proposed pipeline route, ecological features (wetlands) and communities/settlements within the project area	Surface (0-15cm)	Physico-chemical	pH, TPH, PAH, THC, BTEX, Phenols, Percent carbon, Available PO_4^{3-} , Total-N, NH_4^+ , NO_3^- , NO_2^- , Na, K, Ca and Mg, cation exchange capacity, (CEC), conductivity, oil & grease, heavy metals (Fe, Cd, Cr, Pb, Cu, Hg, Ar, Ni, V and Zn, Ba, As)
		Microbiology	Total heterotrophic bacteria and fungi, Total hydrocarbon utilising bacteria and fungi	
2.	Sediment 17 + 2 control Sediment shall be sampled downstream and upstream direction on the major River and its associated channels (creeks and creeklets) within the defined study boundary	Composite Grab samples	Physico-chemical	pH, THC, Percent carbon, Available PO_4 -P, Total-N, NH_4^+ , NO_3^- , NO_2^- , Na ⁺ , K ⁺ , Ca ²⁺ and Mg ²⁺ , Redox potential, oil & grease, heavy metals (Fe, Cd, Cr, Pb, Cu, Ni, V and Zn).
			Microbiology	Total heterotrophic bacteria and fungi, Total hydrocarbon utilising bacteria and fungi
			Sediment characterisation	Colour and texture
			Benthos	Benthic macro-invertebrate studies – identification to the nearest taxonomic level as well as their species distribution, abundance, diversity and density
3.	Surface water 17 + 2 control shall be sampled downstream and upstream direction on the major River and its associated channels (creeks and creeklets) within the defined study boundary	Composite	Physico-chemical	Colour, alkalinity, TDS, TSS, Turbidity, EC, THC, pH, DO, Redox potential, BOD ₅ , COD, Oil & Grease, Anions/Cations, NH_4^+ , NO_3^- , NO_2^- , PO_4 , SO_4^{2-} , SiO_2 , Na ⁺ , K ⁺ , Ca ²⁺ , Mn ²⁺ , Mg ²⁺ . Heavy metals (Fe, Cd, Cr, Ni, V, Pb, Zn, Hg).
			Microbiology	Total heterotrophic bacteria and fungi, Total hydrocarbon utilising bacteria and fungi
			Phytoplankton	Identification to the nearest taxonomic level, Species diversity (composition, distribution and density) and productivity.
			Zooplankton	Identification to the nearest taxonomic level, species diversity (composition, distribution and density)
			Fisheries	Species types and distribution, catch assessment survey (CAS), breeding sites, migration routes, pathology, fisheries activities.
			Aquatic macrophyte	Identification and spatial distribution, biomass per unit area covered, including submerged vegetation, floating and emergent/bank types, <i>aufwuchs</i> * density
			Hydrodynamics	River water depth and width, flow direction and flow rate. River bed current, and tidal information, bathymetric data etc.
4.	Ground-water 11 + 2 control Boreholes shall be drilled within the 2km radius of the field. Two control stations shall be drilled outside the spatial boundary (2km radius) of the field.	Composite	Physico-chemical	Temperature, pH, salinity, EC, DO, Turbidity, THC, Redox potential, oil & grease, anions and cations, heavy metals (Fe, Cd, Cr, Pb, Cu, Ni, V and Zn)
			Hydrodynamics	Water table depth, flow direction and rate.
			Microbiology	Total heterotrophic bacteria and fungi, Total hydrocarbon utilising bacteria and fungi
			Hydrogeology	Stratigraphy of the initial underground layers.
			Log analysis	Physico-chemical and heavy metal characterisation.

S/N	Sample	Sample Type	Analysis	Parameters
5.	Vegetation 7 + 2 control	**Transect area	In situ study Herbarium studies Plants and crops pathological studies	Vegetation types, floral composition Sampled /field unidentifiable plant species Identification of health conditions, insect pests, fungi, bacteria and viral disease of crops around the field and associated villages, farmlands or plantations, plant tissue analysis
6.	Wildlife 7 + 2 control	Transect/ Visual observation	Mammals, reptiles, birds, amphibians and invertebrates	Diversity, distribution, density, conservation status, formal/traditional conservation practices, wildlife exploitation methods.
7.	Air Quality 52 + 2 control Air quality/noise shall cover the proposed Wells locations, River and its associated creeks and creeklets, ecological features (wetlands) and communities/settlements within the project area		Physico- chemical	NOx, SOx, CO, CH4, O2, VOC, Particulates, temperature, heavy metals (Pb, As, Cr, Cd, Hg, Zn, Ni, Fe and Cu) wind speed and direction & noise levels.
8.	Socio-economics	Demography, Social Structure and Organization, Livelihood, Social Infrastructure, Cultural properties, Natural resources and land use, Perception of the project, The role of women and children, Physically challenged, Vehicular/Marine/Boat traffic analysis, Education and Social vices, Economy and Sex trade.		

4. Furthermore, we request that the draft Environmental Impact Assessment (EIA) study report be forwarded to the DPR in both hard and electronic copies. The electronic copy of the study report should be submitted on a compact disc (CD).

5. Finally, you are required to liaise with our Port Harcourt Zonal office to ensure adequate representation of the DPR during the field data gathering exercise and laboratory analysis.

Yours faithfully,

Dr. Musa M. Zagi spe mei

for: Director of Petroleum Resources

Appendix 2 Methodology

Field and Laboratory Procedures

Climate and Air Quality

During the field sampling campaign, climate and meteorological parameters collected were wind speed and direction, ambient air temperature, atmospheric pressure and relative humidity. The gaseous air pollutants measured included ammonia (NH₃), Carbon monoxide (CO), Nitrogen dioxide (NO₂), Sulphur dioxide (SO₂), and Volatile Organic Compounds (VOCs). In addition, the ambient air was analysed for suspended particulate matter (SPM). Online monitors were used to obtain real-time measurements for the air quality and microclimatic parameters.

Meteorological Measurements

Weather Tracker Kestrel 4500 was used for the measurements of meteorological parameters. This Weather Tracker is a sophisticated, multi-function environmental monitoring instrument used to measure major environmental conditions including Barometric Pressure, Temperature, Humidity, Wind Speed and Wind direction.

Air Quality Measurements

Particulates

Particulate matter (PM) was measured with GT-331 Particle Mass Monitor, an equipment from Met One Instruments. It is handheld, battery operated and completely portable unit measuring five mass ranges of TSP: PM₁, PM_{2.5}, PM₇, PM₁₀, and TSP with a concentration range of 0 – 10 mg/m³ (and resolution of 0.1 µg/m³), a sampling time of 2 minutes and a flow rate of 2.83 l/min. To measure, it is placed at 1 m above the ground level, switched on in the environment of interest and the measured concentration read directly on the screen after particle capturing.

Gaseous Pollutants

Ammonia (NH₃), Carbon monoxide (CO), Nitrogen dioxide (NO₂), Sulphur dioxide (SO₂), Hydrogen sulphide (H₂S) and Volatile Organic Compounds (VOCs) gaseous air pollutants were monitored during the study in the ambient environment of the project site using various methods of sampling as described below:

Ammonia (NH₃): NH₃ measurements were taken using an in situ non-integrated single gas ammonia monitor (ToxiRAE Model PGM-1150). The monitor is a measuring instrument with an instantaneous direct readout displays through which current ammonia concentrations can be continuously monitored in ppm (parts per million). It has detection range of 0 – 20 ppm with 0.1 ppm resolution.

Carbon Monoxide (CO): CO measurements were taken using an *in situ* non-integrated single gas carbon monoxide monitor (ToxiRAE Model PGM-1150). The monitor is a 9.3 cm x 4.9 cm x 2.2

cm measuring instrument weighing about 0.1 kg with an instantaneous direct readout displays through which current carbon monoxide concentrations can be continuously monitored in ppm (parts per million). It has detection range of 0 – 500 ppm with 1 ppm resolution.

Oxides of Nitrogen (NO_x): NO_x concentrations were measured as NO₂ using in situ single gas NO₂ monitor (ToxiRAE Model PGM-1120). The monitor is a measuring instrument with an instantaneous direct readout displays through which current NO₂ concentrations can be continuously monitored in ppm (parts per million) with a detection range of 0 – 20 ppm and 0.1 ppm resolution.

Sulphur Dioxide (SO₂): To measure the SO₂ concentrations during the field study, an *in situ* single gas SO₂ monitor (ToxiRAE Model PGM-1130) was used. The monitor is a 9.3 cm x 4.9 cm x 2.2 cm measuring instrument weighing about 0.1 kg with an instantaneous direct readout displays through which current SO₂ concentrations can be continuously monitored in ppm (parts per million) with a detection range of 0 – 20 ppm and 0.1 ppm resolution.

Hydrogen Sulphide (H₂S) and Volatile Organic Compounds (VOCs): These compounds were measured using an *in situ* MultiRAE gas monitor (Model PGM50-5P). It is measuring instrument with an instantaneous direct readout displays through which current VOCs and H₂S concentrations can be continuously monitored in ppm (parts per million). It has detection range of 0 – 20 ppm with 0.1 ppm resolution.

Noise Survey

Noise measurements were taken with a digital, battery-powered, sound pressure level meter (pre-calibrated BK precision 732 sound level meters). To measure the noise levels at any of the sampling locations, the sound level meter was placed at a distance of at least 3 m from any barrier or other sound reflecting sources and at about 1.2 – 1.5 m above ground level. Measurements were taken by setting the sound level meter to the “A” weighting network.

Soil studies

The soil sampling stations were positioned in a stratified grid pattern (IITA 1979). In the grids were cells of approximately 100 m² each from which soil samples were collected. This sampling location pattern was with a view to also ensuring that adequate representative soil samples were collected. A hand-held Dutch type Soil Auger was used to collect representative soil sample at each soil sampling location. At each sampling station and soil depth (0-15 cm, and 15-30cm) for top soil and sub soil levels respectively composite soil samples were collected bulked and thoroughly mixed for homogenization in a plastic bag. The surface and the subsurface level are depths at which most chemical and nutrient elements are most readily available for plants absorption.

Soil samples for physical and nutrient elements analyses were sub sampled into polyethylene bags that had been appropriately labeled with masking tape and indelible ink to indicate sample location and soil depth level. Soil samples for microbial characteristics were sub sampled into sterilized bottles, while samples for hydrocarbon contents were collected into aluminum foils, wrapped up and labeled appropriately also with masking tape and indelible ink. Field and in-situ physical attributes of the sampled soils such as colour, texture, and structure were noted using the Munsell Soil Colour Chart with reference to the combination in the Munsell system of time, values, hue and by rolling the soil samples in between fingers. All in-situ observations were recorded in a field notebook.

Vegetation

The method adopted with modifications was that of Peet, *et al.* (1988) and has been adopted by the North Carolina vegetation survey as its standard vegetation sampling method (Peet, *et al.*, 1997). Basically the method employs a set of 10 modules (sub plots) in a 20 meters X 50 meters layout. The grids are located such that the long axis of the plot is oriented to minimize environmental heterogeneity within the plot. However, in adopting the method for this work, the modules were neglected and the dimension of the plot area was reduced to 10 meters X 40 meters.

A panoramic view of each site and the dominant vegetation type present was used to characterize the overall vegetation type. Systematic randomized sampling was used to observe plants communities and different vegetation types within the spatial boundaries of the facilities with Control points taken outside the defined spatial boundary. Phytosociological and floristic analyses were done by visual inspection. The Vegetation consultant moved randomly on each designated sampling site observing and collecting plants. Photographs were taken to document the general views of each site. For documentation and for detailed determination of species, plant specimens were collected, described, pressed and taken to the herbarium at University of Benin for drying and identification. Plants were categorized according to their taxonomy, growth form, native origin, and primary and secondary uses.

Within the layout, the plant species were enumerated and identified to species and genera as far as possible. Standard quantitative floristic information such as density, relative cover and abundance were recorded (Lewis and Taylor, 1972). Random samples were taken along the survey route in the vegetation communities.

Wildlife studies

Interviews

The wildlife assessment involved a survey of amphibians, reptiles, birds, and mammals in the study areas following methodology described by Agbagwa and Ndukwu (2014). Due to special security constraints prevailing in the Niger Delta areas, night surveillance which would have been ideal for most nocturnal fauna was impossible. To augment this, recent available reports on the fauna pertaining to the Niger Delta were used instead (Powell, 1994; Baker and Olubode (2007);

Luiselli *et al.*, (2015) and Wikipedia (2015). Other members of the fauna observed were photographed *in-situ*, identified and presented. In addition field based interviews were conducted to collect wildlife biodiversity data by discussing with local hunters and farmers. The people had earlier been briefed of the purpose of the survey and the benefits to the community. They provided names of birds, reptiles, amphibians and mammals in their local vernacular.

Transect surveys (Observations)

In each transect of about 50 meters apart, the survey team walked through the transect recording animals sighted. The presence of animals was also inferred from indices like dung, burrows, footprints, claw marks, nests and feathers where available.

Aquatic Studies

Surface Water

The surface water samples were collected and preserved according to standard methods in relation to the parameters to be determined. The water for Dissolved Oxygen (DO) and Biochemical Oxygen Demand (BOD) were collected using a 250 ml reagent glass bottles. The samples were filled and stoppered under the water. After the collections, the DO samples were fixed immediately with Winklers A and B solutions while that of BOD were wrapped with Aluminium foil and tied up in a black polythene bags and put in a cooler.

- Samples for oil and grease were collected with a wide mouth Oil and Grease Sample bottles
- Heavy metals were collected with 250ml plastic bottles and fixed with a few drops of Concentrate Nitric Acid.
- Samples for microbiology were collected in a sterilized McCartney bottle directly from the water bodies.
- Water samples for other physico-chemical analysis were also collected in labeled plastic containers and preserved in ice-cooler.

Water temperature and dissolved oxygen were measured using SHOTT temperature meter (Model 896) with sensitivity of 0.1°C temperature. Conductivity was measured using WTW LF 90 conductivity meter with sensitivity of 0.01 ($\mu\text{S}/\text{cm}$) of conductivity. Salinity was measured using ATAGO refractometer with a sensitivity of 0.5 ppt of salinity.

Sediment Studies

Samples for physicochemical parameters were rapped up in polythene bags and aluminium foils for microbial studies respectively after the sediment for benthic studies have been removed.

Hydrobiological Studies

Plankton Studies

The samples were collected by filtering 60 litres of surface water through 55µ plankton net and the filtrate was poured into a 250ml plastic container and preserved with 4% Formalin.

Benthic Studies

The upper part of the bottom sediments collected for sediment studies were removed, and washed in a sieve. The retained materials in the sieve were placed in wide mouth plastic containers and preserved with 4% Formalin.

Fisheries Studies

Fisheries studies were carried out at the points of surface water collection. The approach used in this study was interviewing the members of the community to get information on the fisheries resources, fishing and preservation methods of the area. This will be complemented by literature survey from research works in those areas.

Hydrogeology

Nine boreholes were drilled within the study area using percussion drilling method (Plates 3.8). Lithologs of the boreholes were recorded. These boreholes were cased using 4” PVC pipes, gravel packed and cemented core samples were collected at every 5ft and analysed for lithological profile. Groundwater samples were collected from these boreholes 24 hours after drilling, with the aid of a Teflon hose while depth to water level was measured using a measuring tape. *In situ* readings for some parameters were taken at the location of the boreholes before the samples were taken to the lab for laboratory analysis.

Social Profile Methodology

Information for this study was obtained from both secondary and primary sources. Reports of earlier impact assessment and related studies in and around the study area, as well as publications of the National Population Commission (NPC); the National Bureau of Statistics (NBS); and other authors were the main secondary sources of information for the study. Primary information was to be obtained from focus group discussion (FGD); Key Informant Interviews (KII); Town Hall Meetings/Participatory Rural Appraisal (PRA), and structured interviews. However, because of security reasons, the Town Hall Meetings and PRA, as well as the structured interviews could not be conducted. In the alternative, representatives of the leadership of each of the stakeholder communities were invited to Yenagoa and consultations held using KII techniques to extract as much information as possible from them. Subsequently, a visit was made the communities for ground trotting and photo shots. The data collected were analyzed and presented in tables, pie charts, histograms, etc.

A total of 43 community leaders drawn from the 5 Clans concerned were involved in the consultations and KII sessions. The distribution is made up as follows:

Emughan Clan	9
Igbuduya Clan	7
Engenni Clan	7
Gbaran Clan	10
Epie Clan	10
Total	43

It is noteworthy to mention that the study area was enmeshed in crisis at the time that this study was carried out. Some communities were almost deserted because of such crisis. For example, in Aminigboko, the traditional ruler and his son were reported murdered as part of community crisis. Schools were forcedly closed in such communities and so it was not possible to visit and interact with pupils and teachers. This scenario had its toll on field data collection.



Appendix 4.1.2
Coordinates of Actual Sampling points

Sample	Description	Eastings	Northings
AIR QUALITY			
AQ1	SOIL	426430	112313
AQ2	SOIL	428907	110058
AQ3	SOIL	428812	108598
AQ4	SOIL	430703	108971
AQ5	SOIL	435457	109105
AQ6	SOIL	434654	108344
AQ7	SOIL	433479	108058
AQ8	SOIL	434114	107199
AQ9	SOIL	439670	109677
AQ10	SOIL	440951	108925
AQ11	SOIL	443067	110185
AQ12	SOIL	443590	109319
AQ13	SOIL	445637	110285
AQ14	SOIL	446062	109708
AQ15	SOIL	453144	106231
AQ16	SOIL	453704	105423
AQ17	SOIL	454148	104470
AQ18	SOIL	459089	104470
AQ19	SOIL	458255	104118
AQ20	SOIL	457882	102946
AQ21	SOIL	453397	103660
AQ22	SOIL	454311	103505
AQ23	SOIL	453882	102925
AQ24	SOIL	454491	102722
AQ25	SOIL	455202	102603
AQ26	SOIL	457624	101689
AQ27	SOIL	456523	100030
AQ28	SOIL	458250	100571
AQ29	SOIL	459199	100775
AQ30	SOIL	459622	100131
AQ31	SOIL	456776	99489
AQ32	SOIL	458894	98946
AQ33	SOIL	461231	102688
AQ34	SOIL	453695	100876
AQ35	SOIL	456134	106210
AQ36	SOIL	454370	109629
AQ37	SOIL	451191	110242
AQ38	SOIL	449089	109902
AQ39	SOIL	447501	110842

Sample	Description	Eastings	Northings
AQ40	SOIL	443434	111375
AQ41	SOIL	440213	112288
AQ42	SOIL	438758	111479
AQ43	SOIL	434522	110706
AQ44	SOIL	429714	112258
AQ45	SOIL	432675	109611
AQ46	SOIL	427767	113901
AQ47	SOIL	437626	110189
AQ48	SOIL	456120	104790
AQ49	SOIL	459854	102459
AQ50	SOIL	454449	108024
AQ51	SOIL	455595	101822
AQ52	SOIL	454854	99679
AQ53	SOIL	457931	99235
AQC1	CONTROL	445409	116817
AQC2	CONTROL	440288	102961
SOIL			
SS1	SOIL	426215	111801
SS2	SOIL	429958	111862
SS3	SOIL	428497	109976
SS4	SOIL	429045	108363
SS5	SOIL	430597	109428
SS6	SOIL	434036	111010
SS7	SOIL	435871	108818
SS8	SOIL	434654	108344
SS9	SOIL	433153	108302
SS10	SOIL	434114	107199
SS11	SOIL	438083	110158
SS12	SOIL	438296	111467
SS13	SOIL	440487	112440
SS14	SOIL	443713	111528
SS15	SOIL	439331	109610
SS16	SOIL	441115	109061
SS17	SOIL	443074	110493
SS18	SOIL	443910	109275
SS19	SOIL	445601	110448
SS20	SOIL	446166	109281
SS21	SOIL	447953	110855
SS22	SOIL	449616	109793
SS23	SOIL	451613	110201
SS24	SOIL	453966	109783
SS25	SOIL	453633	106537

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Sample	Description	Eastings	Northings
SS26	SOIL	456402	106446
SS27	SOIL	453451	105228
SS28	SOIL	453226	103612
SS29	SOIL	454487	103478
SS30	SOIL	453830	103183
SS31	SOIL	454339	102754
SS32	SOIL	455037	102553
SS33	SOIL	454675	100206
SS34	SOIL	456085	104518
SS35	SOIL	457306	103094
SS36	SOIL	457614	101842
SS37	SOIL	456300	100085
SS38	SOIL	456858	99577
SS39	SOIL	458312	100393
SS40	SOIL	459090	100997
SS41	SOIL	459425	100004
SS42	SOIL	458982	99146
SS43	SOIL	461383	102553
SS44	SOIL	459680	102083
SS45	SOIL	454490	107810
SS46	SOIL	455274	99708
SS47	SOIL	455965	101716
SS48	SOIL	457646	99130
SS49	SOIL	455054	103798
SS50	SOIL	427645	113293
SS51	SOIL	455443	100271
SS52	SOIL	454705	99788
SS53	SOIL	455925	100928
SS54	SOIL	456663	100942
SS55	SOIL	456273	100642
SS56	SOIL	456357	101203
SS57	SOIL	457763	99762
SS58	SOIL	458098	99386
SS59	SOIL	457347	99480
SS60	SOIL	459171	102122
SS61	SOIL	459506	102565
SS62	SOIL	459466	101814
SS63	SOIL	455161	103409
SS64	SOIL	454786	103249
SSC1	CONTROL	444509	116755
SSC2	CONTROL	440953	102997
SURFACE WATER/SEDIMENT			

Sample	Description	Eastings	Northings
SWSD1	SURFACE WATER/SEDIMENT	456595	98510
SWSD2	SURFACE WATER/SEDIMENT	456412	102199
SWSD3	SURFACE WATER/SEDIMENT	454529	105586
SWSD4	SURFACE WATER/SEDIMENT	449902	108788
SWSD5	SURFACE WATER/SEDIMENT	455456	110712
SWSD6	SURFACE WATER/SEDIMENT	441035	109436
SWSD7	SURFACE WATER/SEDIMENT	441207	111832
SWSD8	SURFACE WATER/SEDIMENT	435154	110727
SWSD9	SURFACE WATER/SEDIMENT	446704	111035
SWSD10	SURFACE WATER/SEDIMENT	434067	108406
SWSD11	SURFACE WATER/SEDIMENT	456067	100641
SWSD12	SURFACE WATER/SEDIMENT	440818	110764
SWSD13	SURFACE WATER/SEDIMENT	454831	104048
SWSD14	SURFACE WATER/SEDIMENT	454098	103397
SWSD15	SURFACE WATER/SEDIMENT	454909	102916
SWSD16	SURFACE WATER/SEDIMENT	456448	101422
SWSD17	SURFACE WATER/SEDIMENT	455466	101352
SWSDC1	CONTROL	444627	117704
SWSDC2	CONTROL	439555	103806
BOREHOLE			
BH1	BOREHOLE	458900	99436
BH2	BOREHOLE	457098	98984
BH3	BOREHOLE	457516	100806
BH4	BOREHOLE	445361	109693
BH5	BOREHOLE	440908	111969
BH6	BOREHOLE	428401	111157
BH9	BOREHOLE	454450	103758
BH7	BOREHOLE	455347	103667
BH8	BOREHOLE	455081	103195
BHC1	CONTROL	445186	117221
BHC2	CONTROL	440826	102447
VEGETATION			
VG1	VEGETATION	427639	112268
VG2	VEGETATION	433798	109633
VG3	VEGETATION	442053	111252
VG4	VEGETATION	448403	109633
VG5	VEGETATION	455992	108998
VG6	VEGETATION	453521	102356
VG7	VEGETATION	457865	100203
VGC1	CONTROL	446075	117263
VGC2	CONTROL	440667	103709

Appendix 4.6.1
Microclimatic data

Measurements of Meteorological parameters in Enwhe Field during the Wet season

STATION	Air Temp. (°C)		Relative Humidity (%)		Wind Speed (m/s)		Wind direction		Air Turbulence		Atm. Pressure (hpa)	
	WET	DRY	WET	DRY	WET	DRY	WET	DRY	WET	DRY	WET	DRY
AQ1	29.1	36.5	77.6	53.8	2.6	0.7	SW	SW	F	F	1010	1007
AQ2	30.3	35	72.3	63.5	0.8	0.8	SE	SW	F	F	1012	1008
AQ3	31.6	31.9	67.3	61.4	2.1	0.5	SE	SW	F	F	1011	1009
AQ4	33.1	31.7	69.1	57.9	1.2	1	SE	SW	F	F	1013	1009
AQ5	33.2	32.5	84.1	57.8	1.4	3.3	SW	SW	F	F	1014	1011
AQ6	32.1	32.5	76.1	58.3	1.3	1	SW	SW	F	F	1014	1011
AQ7	28.9	32.2	82.5	56.8	1.0	0.4	SW	SW	F	F	1014	1010
AQ8	27.8	26	79.1	71.1	0.6	3.6	SW	SW	F	F	1014	1007
AQ9	30.2	26.6	67.5	74	0.7	0.2	SE	SW	F	F	1011	1007
AQ10	32.0	27.4	79.5	69.3	0.6	3.3	SW	SW	F	F	1013	1007
AQ11	29.6	29.6	81.3	65	0.3	0.6	SW	SW	F	F	1013	1005
AQ12	30.8	NS	64.1	NS	0.1	NS	SW	NS	F	NS	1012	NS
AQ13	31.7	NS	64.5	NS	0.1	NS	SE	NS	F	NS	1011	NS
AQ14	30.8	NS	62.1	NS	0.1	NS	SE	NS	F	NS	1012	NS
AQ15	29.6	NS	59.9	NS	2.4	NS	SW	NS	F	NS	1013	NS
AQ16	30.4	NS	71.7	NS	0.4	NS	E	NS	F	NS	1013	NS
AQ17	30.5	NS	64.8	NS	0.3	NS	SE	NS	F	NS	1012	NS
AQ18	30.9	35.1	63.7	54.3	0.3	0.8	SW	SW	F	F	1011	1005
AQ19	29.8	31.7	58.1	52.6	0.2	0.5	SW	SW	F	F	1010	1008
AQ20	33.4	34	58.2	57	0.5	1.2	SW	SW	F	F	1011	1004
AQ21	28.3	31.8	67.2	61.3	0.3	0.5	SW	SW	F	F	1014	1008
AQ22	29.8	30.2	67.5	56.8	0.5	0.2	W	SW	F	F	1011	1006
AQ23	33.4	30.2	65.9	63.7	0.4	0.3	SW	SW	F	F	1014	1007
AQ24	28.3	30.9	72.1	68	0.4	0.4	E	SW	F	F	1010	1006
AQ25	29.4	31.6	73.7	58	2.4	0.2	SW	SW	F	F	1010	1006
AQ26	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
AQ27	26.4	30.7	81.7	56	0.4	1.5	NE	SW	F	F	1011	1007
AQ28	28.2	34.8	65.3	61.7	0.7	0.7	S	SW	F	F	1009	1008

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STATION	Air Temp. (°C)		Relative Humidity (%)		Wind Speed (m/s)		Wind direction		Air Turbulence		Atm. Pressure (hpa)	
	WET	DRY	WET	DRY	WET	DRY	WET	DRY	WET	DRY	WET	DRY
AQ29	30.1	28.4	75.3	57	0.8	0.4	SW	SW	F	F	1009	1007
AQ30	28.9	29.8	71.3	59.2	0.9	0.3	W	SW	F	F	1009	1007
AQ31	27.2	27.3	64.2	60	1.4	2.2	NE	SW	F	F	1011	1006
AQ32	30.2	34.8	72.5	68.7	0.8	1.5	W	SW	F	F	1011	1009
AQ33	32.1	31	62.8	72.1	0.4	2.4	SW	SW	F	F	1010	1006
AQ34	27.8	30.1	75.2	53.4	0.8	1.2	SW	SW	F	F	1011	1007
AQ35	31.9	30.1	61.8	60.9	0.8	0.4	SW	SW	F	F	1013	1008
AQ36	30.4	NS	73.1	NS	0.5	NS	SE	NS	NS	F	1013	NS
AQ37	29.1	NS	73.2	NS	0.1	NS	SE	NS	NS	F	1013	NS
AQ38	30.8	NS	70.3	NS	0.1	NS	SW	NS	NS	F	1013	NS
AQ39	29.2	30.1	82.4	61	0.6	0.6	NE	SW	F	F	1014	1005
AQ40	30.2	30.1	72.9	56	0.7	0.4	NE	SW	F	F	1014	1006
AQ41	28.0	26.4	81.6	60.9	2.3	2.4	NE	SW	F	F	1010	1006
AQ42	25.2	26.7	95.3	70.8	3.1	0.8	SE	SW	F	F	1011	1006
AQ43	27.0	33.5	92.3	51	3.0	1.4	SW	SW	F	F	1010	1007
AQ44	31.3	31.9	71.8	56.1	1.8	0.8	SE	SW	F	F	1013	1009
AQ45	28.6	33.8	81.7	59.4	2.5	0.4	SW	SW	F	F	1010	1006
AQ46	29.7	26	71.3	71.7	1.1	0.4	NW	SW	F	F	1010	1006
AQ47	31.2	27.9	71.9	73.9	0.9	2.4	N	SW	F	F	1013	1005
AQ48	27.0	35.0	66.7	57.3	0.2	0.8	SW	SW	F	F	1010	1005
AQ49	31.6	30.1	62	59.1	0.2	0.3	SW	SW	F	F	1013	1005
AQ50	27.0	29.5	70.4	56	2.5	0.4	S	SW	F	F	1012	1006
AQ51	27.0	32.0	81.7	61.1	0.1	1.2	SW	SW	F	F	1012	1007
AQ52	28.0	26.6	68.1	44.7	0.4	0.4	W	SW	F	F	1010	1009
AQC1	33.2	29.6	70.9	57.3	0.6	2	NW	SW	F	F	1010	1007
AQC2	31.7	29.7	69.7	72.1	0.5	1	SE	SW	F	F	1012	1008

Appendix 4.6.2a

Measurements of Air Pollutants in Enwhe Field during the wet season

STATION	SPM ($\mu\text{g}/\text{m}^3$)	NO ₂ (ppm)	SO ₂ (ppm)	H ₂ S (ppm)	NH ₃ (ppm)	CO (ppm)	VOC (ppm)	O ₃ (ppm)	Noise dB(A)
AQ1	0.5	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	51.5
AQ2	0.1	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	48.4
AQ3	2.1	0.001	<0.001	<0.001	<0.001	0.005	<0.001	<0.001	64
AQ4	1.2	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	50.5
AQ5	1.2	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	70.6
AQ6	0.8	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	63.6
AQ7	1.5	0.002	<0.001	<0.001	0.001	0.001	<0.001	<0.001	62.3
AQ8	2.3	0.001	<0.001	<0.001	0.001	0.003	<0.001	<0.001	72.4
AQ9	0.9	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	52.5
AQ10	0.2	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	52.8
AQ11	0.6	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	81.3
AQ12	0.4	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	37.3
AQ13	0.01	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	33.8
AQ14	0.01	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	34.3
AQ15	0.3	0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	42.7
AQ16	0.5	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	39.6
AQ17	0.1	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	41.3
AQ18	0.84	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	48.5
AQ19	1.35	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	65.9
AQ20	1.11	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	51.8
AQ21	0.6	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	52
AQ22	1	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	56.1
AQ23	0.4	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	50.6
AQ24	0.4	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	45.3
AQ25	0.2	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	40.3
AQ27	0.51	0.002	<0.001	<0.001	0.001	0.001	<0.001	<0.001	51.6
AQ28	1.2	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	51.8
AQ29	0.81	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	44.8
AQ30	1.05	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	49.4
AQ31	0.8	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	52.7
AQ32	0.53	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	57.8
AQ33	2.19	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	59.5
AQ34	1.2	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	61.9
AQ35	1.3	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	48.9

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STATION	SPM ($\mu\text{g}/\text{m}^3$)	NO ₂ (ppm)	SO ₂ (ppm)	H ₂ S (ppm)	NH ₃ (ppm)	CO (ppm)	VOC (ppm)	O ₃ (ppm)	Noise dB(A)
AQ36	0.1	<0.001	<0.001	<0.001	<0.001	0.004	<0.001	<0.001	42.2
AQ37	0.1	<0.001	<0.001	<0.001	<0.001	0.003	<0.001	<0.001	54.1
AQ38	0.1	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	48.5
AQ39	0.4	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	64.1
AQ40	0.2	<0.001	<0.001	<0.001	0.001	0.001	<0.001	<0.001	64.4
AQ41	0.3	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	66.5
AQ42	0.6	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	69.7
AQ43	0.3	<0.001	<0.001	<0.001	<0.001	0.003	<0.001	<0.001	74.2
AQ44	1.5	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	56.5
AQ45	1.2	<0.001	0.001	<0.001	<0.001	0.002	<0.001	<0.001	76.9
AQ46	0.5	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	48.3
AQ47	1.1	0.002	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	51.6
AQ48	1.33	<0.001	<0.001	<0.001	<0.001	0.002	<0.001	<0.001	59.5
AQ49	0.7	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	45.5
AQ50	1.21	0.001	<0.001	<0.001	0.002	<0.001	<0.001	<0.001	55.4
AQ51	1.5	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	56.4
AQ52	1.25	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	48.1
AQC1	1.2	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	46.3
AQC2	2.5	0.001	0.001	<0.001	0.001	0.002	0.001	<0.001	55.7

Appendix 4.6.2b

Measurements of Air Pollutants in Enwhe Field during the dry season

STATION	SPM ($\mu\text{g}/\text{m}^3$)	NO ₂ (ppm)	SO ₂ (ppm)	H ₂ S (ppm)	NH ₃ (ppm)	CO (ppm)	VOC (ppm)	O ₃ (ppm)	Noise (dB(A))
AQ1	1.58	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	45.7
AQ2	1.12	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	53.3
AQ3	2.05	0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	66.4
AQ4	1.05	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	47.3
AQ5	3.01	<0.001	<0.001	<0.001	<0.001	0.003	<0.001	<0.001	69
AQ6	2.05	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	65.4
AQ7	1.07	<0.001	<0.001	<0.001	0.002	0.002	<0.001	<0.001	49.9
AQ8	4.09	0.001	<0.001	<0.001	<0.001	0.005	0.002	<0.001	68.1
AQ9	1.07	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	48.2
AQ10	2.59	<0.001	<0.001	<0.001	<0.001	0.002	<0.001	<0.001	55.4
AQ11	0.5	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	55.4
AQ12	NS	NS	NS	NS	NS	NS	NS	NS	NS
AQ13	NS	NS	NS	NS	NS	NS	NS	NS	NS
AQ14	NS	NS	NS	NS	NS	NS	NS	NS	NS
AQ15	NS	NS	NS	NS	NS	NS	NS	NS	NS
AQ16	NS	NS	NS	NS	NS	NS	NS	NS	NS
AQ17	NS	NS	NS	NS	NS	NS	NS	NS	NS
AQ18	0.81	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	48.1
AQ19	1.21	<0.001	<0.001	<0.001	<0.001	0.004	<0.001	<0.001	53.9
AQ20	1.93	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	53.4
AQ21	1.2	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	50.3
AQ22	0.4	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	47.1
AQ23	0.8	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	45.5
AQ24	0.5	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	46.9
AQ25	0.52	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	45.7
AQ26	NS	NS	NS	NS	NS	NS	NS	NS	NS
AQ27	2.07	0.002	<0.001	<0.001	0.001	0.001	<0.001	<0.001	50.2
AQ28	0.82	<0.001	<0.001	<0.001	<0.001	0.003	<0.001	<0.001	56.1
AQ29	3.53	<0.001	<0.001	<0.001	<0.001	0.005	<0.001	<0.001	49.7
AQ30	1.05	<0.001	<0.001	<0.001	<0.001	0.01	<0.001	<0.001	50.3
AQ31	3.71	<0.001	<0.001	<0.001	<0.001	0.07	<0.001	<0.001	49.9
AQ32	3.53	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	53.3
AQ33	0.13	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	46.5

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STATION	SPM ($\mu\text{g}/\text{m}^3$)	NO ₂ (ppm)	SO ₂ (ppm)	H ₂ S (ppm)	NH ₃ (ppm)	CO (ppm)	VOC (ppm)	O ₃ (ppm)	Noise (dB(A))
AQ34	1.01	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	51.5
AQ35	0.35	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	47.9
AQ36	NS	NS	NS	NS	NS	NS	NS	NS	NS
AQ37	NS	NS	NS	NS	NS	NS	NS	NS	NS
AQ38	NS	NS	NS	NS	NS	NS	NS	NS	NS
AQ39	3.04	<0.001	<0.001	<0.001	<0.001	0.004	<0.001	<0.001	55.9
AQ40	2.12	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	57.6
AQ41	3.07	0.001	<0.001	<0.001	0.001	0.003	<0.001	<0.001	56.7
AQ42	3.45	0.001	0.001	<0.001	0.001	0.005	0.002	<0.001	51.3
AQ43	3.04	<0.001	0.001	<0.001	<0.001	0.003	0.001	<0.001	67.5
AQ44	1.05	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	45.1
AQ45	2.05	0.001	0.001	<0.001	<0.001	0.004	<0.001	<0.001	69.3
AQ46	2.01	<0.001	<0.001	<0.001	<0.001	0.002	<0.001	<0.001	57.2
AQ47	2.42	0.002	<0.001	<0.001	<0.001	0.01	<0.001	<0.001	51.7
AQ48	7.06	<0.001	<0.001	<0.001	<0.001	0.04	<0.001	<0.001	53.1
AQ49	0.5	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	44.8
AQ50	1.15	0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	49
AQ51	3.41	<0.001	<0.001	<0.001	<0.001	0.002	<0.001	<0.001	52.1
AQ52	1.51	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	54.2
AQC1	0.6	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	53.6
AQC2	3.01	0.001	0.001	<0.001	0.001	0.002	0.002	<0.001	57

Appendix 4.6.2c

Measurements of heavy metals in Air in Enwhe Field during the wet season

S/N	PARAMETER	Pb (ppm)	As (ppm)	Cr (ppm)	Cd (ppm)	Hg (ppm)	Zn (ppm)	Ni (ppm)	Fe (ppm)	Cu (ppm)
1	AQ 1	<0.001	<0.05	<0.005	<0.001	<0.05	<0.001	<0.005	<0.001	<0.001
2	AQ 2	<0.001	<0.05	<0.005	<0.001	<0.05	<0.001	<0.005	<0.001	<0.001
3	AQ 3	<0.001	<0.05	<0.005	<0.001	<0.05	<0.001	<0.005	<0.001	<0.001
4	AQ 4	<0.001	<0.05	<0.005	<0.001	<0.05	<0.001	<0.005	<0.001	<0.001
5	AQ 5	<0.001	<0.05	<0.005	<0.001	<0.05	<0.001	<0.005	<0.001	<0.001
6	AQ 6	<0.001	<0.05	<0.005	<0.001	<0.05	<0.001	<0.005	<0.001	<0.001
7	AQ 7	<0.001	<0.05	<0.005	<0.001	<0.05	<0.001	<0.005	<0.001	<0.001
8	AQ 8	<0.001	<0.05	<0.005	<0.001	<0.05	<0.001	<0.005	<0.001	<0.001
9	AQ 9	<0.001	<0.05	<0.005	<0.001	<0.05	<0.001	<0.005	<0.001	<0.001
10	AQ 10	<0.001	<0.05	<0.005	<0.001	<0.05	<0.001	<0.005	<0.001	<0.001
11	AQ 11	<0.001	<0.05	<0.005	<0.001	<0.05	<0.001	<0.005	<0.001	<0.001
12	AQ 12	<0.001	<0.05	<0.005	<0.001	<0.05	<0.001	<0.005	<0.001	<0.001
13	AQ 13	<0.001	<0.05	<0.005	<0.001	<0.05	<0.001	<0.005	<0.001	<0.001
14	AQ 14	<0.001	<0.05	<0.005	<0.001	<0.05	<0.001	<0.005	<0.001	<0.001
15	AQ 15	<0.001	<0.05	<0.005	<0.001	<0.05	<0.001	<0.005	<0.001	<0.001
16	AQ 16	<0.001	<0.05	<0.005	<0.001	<0.05	<0.001	<0.005	<0.001	<0.001
17	AQ 17	<0.001	<0.05	<0.005	<0.001	<0.05	<0.001	<0.005	<0.001	<0.001
18	AQ 18	<0.001	<0.05	<0.005	<0.001	<0.05	<0.001	<0.005	<0.001	<0.001
19	AQ 19	<0.001	<0.05	<0.005	<0.001	<0.05	<0.001	<0.005	<0.001	<0.001
20	AQ 20	<0.001	<0.05	<0.005	<0.001	<0.05	<0.001	<0.005	<0.001	<0.001
21	AQ 21	<0.001	<0.05	<0.005	<0.001	<0.05	<0.001	<0.005	<0.001	<0.001
22	AQ 22	<0.001	<0.05	<0.005	<0.001	<0.05	<0.001	<0.005	<0.001	<0.001
23	AQ 23	<0.001	<0.05	<0.005	<0.001	<0.05	<0.001	<0.005	<0.001	<0.001
24	AQ 24	<0.001	<0.05	<0.005	<0.001	<0.05	<0.001	<0.005	<0.001	<0.001
25	AQ 25	<0.001	<0.05	<0.005	<0.001	<0.05	<0.001	<0.005	<0.001	<0.001
26	AQ 27	<0.001	<0.05	<0.005	<0.001	<0.05	<0.001	<0.005	<0.001	<0.001

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S/N	PARAMETER	Pb (ppm)	As (ppm)	Cr (ppm)	Cd (ppm)	Hg (ppm)	Zn (ppm)	Ni (ppm)	Fe (ppm)	Cu (ppm)
27	AQ 28	<0.001	<0.05	<0.005	<0.001	<0.05	<0.001	<0.005	<0.001	<0.001
28	AQ 29	<0.001	<0.05	<0.005	<0.001	<0.05	<0.001	<0.005	<0.001	<0.001
29	AQ 30	<0.001	<0.05	<0.005	<0.001	<0.05	<0.001	<0.005	<0.001	<0.001
30	AQ 31	<0.001	<0.05	<0.005	<0.001	<0.05	<0.001	<0.005	<0.001	<0.001
31	AQ 32	<0.001	<0.05	<0.005	<0.001	<0.05	<0.001	<0.005	<0.001	<0.001
32	AQ 33	<0.001	<0.05	<0.005	<0.001	<0.05	<0.001	<0.005	<0.001	<0.001
33	AQ 34	<0.001	<0.05	<0.005	<0.001	<0.05	<0.001	<0.005	<0.001	<0.001
34	AQ 35	<0.001	<0.05	<0.005	<0.001	<0.05	<0.001	<0.005	<0.001	<0.001
35	AQ 36	<0.001	<0.05	<0.005	<0.001	<0.05	<0.001	<0.005	<0.001	<0.001
36	AQ 37	<0.001	<0.05	<0.005	<0.001	<0.05	<0.001	<0.005	<0.001	<0.001
37	AQ 38	<0.001	<0.05	<0.005	<0.001	<0.05	<0.001	<0.005	<0.001	<0.001
38	AQ 39	<0.001	<0.05	<0.005	<0.001	<0.05	<0.001	<0.005	<0.001	<0.001
39	AQ 40	<0.001	<0.05	<0.005	<0.001	<0.05	<0.001	<0.005	<0.001	<0.001
40	AQ 41	<0.001	<0.05	<0.005	<0.001	<0.05	<0.001	<0.005	<0.001	<0.001
41	AQ 42	<0.001	<0.05	<0.005	<0.001	<0.05	<0.001	<0.005	<0.001	<0.001
42	AQ 43	<0.001	<0.05	<0.005	<0.001	<0.05	<0.001	<0.005	<0.001	<0.001
43	AQ 44	<0.001	<0.05	<0.005	<0.001	<0.05	<0.001	<0.005	<0.001	<0.001
44	AQ 45	<0.001	<0.05	<0.005	<0.001	<0.05	<0.001	<0.005	<0.001	<0.001
45	AQ 46	<0.001	<0.05	<0.005	<0.001	<0.05	<0.001	<0.005	<0.001	<0.001
46	AQ 47	<0.001	<0.05	<0.005	<0.001	<0.05	<0.001	<0.005	<0.001	<0.001
47	AQ 48	<0.001	<0.05	<0.005	<0.001	<0.05	<0.001	<0.005	<0.001	<0.001
48	AQ 49	<0.001	<0.05	<0.005	<0.001	<0.05	<0.001	<0.005	<0.001	<0.001
49	AQ 50	<0.001	<0.05	<0.005	<0.001	<0.05	<0.001	<0.005	<0.001	<0.001
50	AQ 51	<0.001	<0.05	<0.005	<0.001	<0.05	<0.001	<0.005	<0.001	<0.001
51	AQ 52	<0.001	<0.05	<0.005	<0.001	<0.05	<0.001	<0.005	<0.001	<0.001
52	AQ C1	<0.001	<0.05	<0.005	<0.001	<0.05	<0.001	<0.005	<0.001	<0.001
53	AQ C2	<0.001	<0.05	<0.005	<0.001	<0.05	<0.001	<0.005	<0.001	<0.001

Appendix 4.6.2d:

Measurements of heavy metals in Air in Enwhe Field during the dry season

S/N	PARAMETER	Pb (ppm)	As (ppm)	Cr (ppm)	Cd (ppm)	Hg (ppm)	Zn (ppm)	Ni (ppm)	Fe (ppm)	Cu (ppm)
1	AQ 1	<0.001	<0.05	<0.005	<0.001	<0.05	<0.001	<0.005	<0.001	<0.001
2	AQ 2	<0.001	<0.05	<0.005	<0.001	<0.05	<0.001	<0.005	<0.001	<0.001
3	AQ 3	<0.001	<0.05	<0.005	<0.001	<0.05	<0.001	<0.005	<0.001	<0.001
4	AQ 4	<0.001	<0.05	<0.005	<0.001	<0.05	<0.001	<0.005	<0.001	<0.001
5	AQ 5	<0.001	<0.05	<0.005	<0.001	<0.05	<0.001	<0.005	<0.001	<0.001
6	AQ 6	<0.001	<0.05	<0.005	<0.001	<0.05	<0.001	<0.005	<0.001	<0.001
7	AQ 7	<0.001	<0.05	<0.005	<0.001	<0.05	<0.001	<0.005	<0.001	<0.001
8	AQ 8	<0.001	<0.05	<0.005	<0.001	<0.05	<0.001	<0.005	<0.001	<0.001
9	AQ 9	<0.001	<0.05	<0.005	<0.001	<0.05	<0.001	<0.005	<0.001	<0.001
10	AQ 10	<0.001	<0.05	<0.005	<0.001	<0.05	<0.001	<0.005	<0.001	<0.001
11	AQ 11	<0.001	<0.05	<0.005	<0.001	<0.05	<0.001	<0.005	<0.001	<0.001
12	AQ 12	<0.001	<0.05	<0.005	<0.001	<0.05	<0.001	<0.005	<0.001	<0.001
13	AQ 13	<0.001	<0.05	<0.005	<0.001	<0.05	<0.001	<0.005	<0.001	<0.001
14	AQ 14	<0.001	<0.05	<0.005	<0.001	<0.05	<0.001	<0.005	<0.001	<0.001
15	AQ 15	<0.001	<0.05	<0.005	<0.001	<0.05	<0.001	<0.005	<0.001	<0.001
16	AQ 16	<0.001	<0.05	<0.005	<0.001	<0.05	<0.001	<0.005	<0.001	<0.001
17	AQ 17	<0.001	<0.05	<0.005	<0.001	<0.05	<0.001	<0.005	<0.001	<0.001
18	AQ 18	<0.001	<0.05	<0.005	<0.001	<0.05	<0.001	<0.005	<0.001	<0.001
19	AQ 19	<0.001	<0.05	<0.005	<0.001	<0.05	<0.001	<0.005	<0.001	<0.001
20	AQ 20	<0.001	<0.05	<0.005	<0.001	<0.05	<0.001	<0.005	<0.001	<0.001
21	AQ 21	<0.001	<0.05	<0.005	<0.001	<0.05	<0.001	<0.005	<0.001	<0.001
22	AQ 22	<0.001	<0.05	<0.005	<0.001	<0.05	<0.001	<0.005	<0.001	<0.001
23	AQ 23	<0.001	<0.05	<0.005	<0.001	<0.05	<0.001	<0.005	<0.001	<0.001
24	AQ 24	<0.001	<0.05	<0.005	<0.001	<0.05	<0.001	<0.005	<0.001	<0.001
25	AQ 25	<0.001	<0.05	<0.005	<0.001	<0.05	<0.001	<0.005	<0.001	<0.001
26	AQ 27	<0.001	<0.05	<0.005	<0.001	<0.05	<0.001	<0.005	<0.001	<0.001

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S/N	PARAMETER	Pb (ppm)	As (ppm)	Cr (ppm)	Cd (ppm)	Hg (ppm)	Zn (ppm)	Ni (ppm)	Fe (ppm)	Cu (ppm)
27	AQ 28	<0.001	<0.05	<0.005	<0.001	<0.05	<0.001	<0.005	<0.001	<0.001
28	AQ 29	<0.001	<0.05	<0.005	<0.001	<0.05	<0.001	<0.005	<0.001	<0.001
29	AQ 30	<0.001	<0.05	<0.005	<0.001	<0.05	<0.001	<0.005	<0.001	<0.001
30	AQ 31	<0.001	<0.05	<0.005	<0.001	<0.05	<0.001	<0.005	<0.001	<0.001
31	AQ 32	<0.001	<0.05	<0.005	<0.001	<0.05	<0.001	<0.005	<0.001	<0.001
32	AQ 33	<0.001	<0.05	<0.005	<0.001	<0.05	<0.001	<0.005	<0.001	<0.001
33	AQ 34	<0.001	<0.05	<0.005	<0.001	<0.05	<0.001	<0.005	<0.001	<0.001
34	AQ 35	<0.001	<0.05	<0.005	<0.001	<0.05	<0.001	<0.005	<0.001	<0.001
35	AQ 36	<0.001	<0.05	<0.005	<0.001	<0.05	<0.001	<0.005	<0.001	<0.001
36	AQ 37	<0.001	<0.05	<0.005	<0.001	<0.05	<0.001	<0.005	<0.001	<0.001
37	AQ 38	<0.001	<0.05	<0.005	<0.001	<0.05	<0.001	<0.005	<0.001	<0.001
38	AQ 39	<0.001	<0.05	<0.005	<0.001	<0.05	<0.001	<0.005	<0.001	<0.001
39	AQ 40	<0.001	<0.05	<0.005	<0.001	<0.05	<0.001	<0.005	<0.001	<0.001
40	AQ 41	<0.001	<0.05	<0.005	<0.001	<0.05	<0.001	<0.005	<0.001	<0.001
41	AQ 42	<0.001	<0.05	<0.005	<0.001	<0.05	<0.001	<0.005	<0.001	<0.001
42	AQ C1	<0.001	<0.05	<0.005	<0.001	<0.05	<0.001	<0.005	<0.001	<0.001
43	AQ C2	<0.001	<0.05	<0.005	<0.001	<0.05	<0.001	<0.005	<0.001	<0.001

Appendix 4.6.3a:

Measurements of physicochemical parameters in surface water in Enwhe Field during the wet season

S/ N	PARAMETER	UNIT	S W1	SW 2	S W3	S W4	S W5	S W6	S W7	SW 8	S W9	SW 10	SW 11	SW 12	SW 13	SW 14	SW 15	SW 16	SW 17	SWC TRL 1	SWC TRL 2
1	pH		7.24	7.38	6.35	7.02	6.50	6.87	6.90	7.23	7.80	7.16	7.12	7.50	7.50	5.52	5.48	7.04	7.00	6.70	7.19
2	Redox Potential	mV	-31.80	-42.50	10.50	-8.50	13.10	11.90	11.10	-32.80	-59.30	-28.70	-29.10	-46.30	45.90	92.30	91.8	-11.7	-9.2	14.8	-13.5
3	Electrical Conductivity	µS/cm	18.30	132.80	11.40	23.60	13.70	20.30	39.30	47.00	33.50	47.00	17.20	21.00	19.30	9.81	10.54	18.20	17.30	38.70	38.70
4	Turbidity	NTU	51.3	160.4	33.4	169.0	169.2	58.2	81.6	62.4	249.6	31.7	42.6	49.6	112.4	5.2	26.4	59.1	84.4	21000.0	9090.0
5	TSS	mg/L	26.0	90.0	20.0	114.0	111.0	49.0	78.0	48.0	176.0	27.0	38.0	34.0	89.0	4.0	24.0	38.0	68.0	29.0	24.0
6	TDS	mg/L	9.60	66.40	5.80	11.80	7.30	10.20	19.70	23.60	16.80	23.50	8.60	10.80	9.70	4.90	5.30	9.40	8.80	19.40	19.40
11	Salinity as Cl	mg/L	3.79	41.48	1.56	3.22	5.57	1.11	8.69	5.12	2.00	6.90	1.11	2.90	1.56	1.11	1.11	1.11	3.22	97.76	5.12
12	Odour	TON	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
13	Nitrite	mg/L	0.026	0.072	0.024	0.045	0.069	0.030	0.020	0.033	0.097	0.021	0.025	0.017	0.055	0.098	0.012	0.027	0.039	0.012	0.018
14	Colour	mg/L	11	18	17	12	28	20	29	14	14	26	19	21	28	29	7	13	11	25	20
15	Alkalinity	mg/L	29.00	31.50	29.00	34.00	29.00	31.50	31.50	34.00	36.50	31.50	29.00	31.50	31.50	24.00	26.50	34.00	34.00	31.50	39.00
16	Oil & Grease	mg/L	1.6	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	1.3	<0.1	0.35	<0.1	<0.1	<0.1	<0.1
17	Nitrate	mg/L	0.213	0.371	0.143	2.304	0.257	0.108	0.187	0.178	0.134	0.073	0.108	0.161	0.108	0.143	0.161	0.240	0.117	0.143	0.126
18	Phenols	mg/L	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
19	Sulphate	mg/L	2.13	5.87	1.82	1.67	1.89	2.44	2.35	2.43	1.57	8.05	2.52	2.19	3.18	0.89	1.17	2.17	2.95	6.36	3.03
20	Ammonia	mg/L	0.987	1.522	1.104	2.105	1.805	1.075	1.069	0.857	2.323	3.080	0.969	1.069	1.334	1.069	0.781	0.999	1.246	0.863	0.710

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S/ N	PARAM ETER	UN IT	S W1	SW 2	S W3	S W4	S W5	S W6	S W7	SW 8	S W9	SW 10	SW 11	SW 12	SW 13	SW 14	SW 15	SW 16	SW 17	SWC TRL 1	SWC TRL 2
21	Phosphate	mg/ L	0.1 14	0.39 3	0.1 13	0.1 05	0.2 85	0.1 34	0.2 38	0.5 25	0.6 29	0.7 26	0.2 24	0.1 58	0.3 57	0.0 47	0.0 75	0.1 82	0.0 91	0.103	0.115
22	reactive silica	mg/ L	0.6 1	0.65	0.7 8	0.7 8	0.8 3	0.7 8	1.0 8	0.9 8	1.4 2	1.4 9	1.4 2	1.4 2	1.4 7	0.9 2	0.8 9	1.3 2	1.4 1	1.46	1.03

Appendix 4.6.3b:

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Measurements of physicochemical parameters in surface water in Enwhe Field during the dry season

S/ N	PARAMETER	UNIT	SW 1	SW 2	SW 4	SW5	SW6	SW7	SW 9	SW1 0	SW1 1	SW1 2	SW1 3	SW1 6	SW1 7	SWCTR L 1	SWCTR L 2
1	pH		7.09	7.10	6.70	6.30	7.20	6.71	7.30	6.70	7.10	6.90	7.02	7.14	7.30	6.68	7.40
2	Redox Potential	mV	-30.80	-30.60	-16.50	-12.40	-32.10	-15.20	-32.90	-15.90	-28.80	-28.10	-29.50	-31.5	-32.6	-18.4	-33.5
3	Electrical Conductivity	µS/cm	15.50	30.10	18.40	34.30	18.90	15.60	72.50	70.20	16.40	16.00	14.60	15.80	16.20	24.50	52.30
4	Turbidity	NTU	21.4	5.9	34.0	4.4	20.0	19.3	12.5	12.0	16.8	43.0	19.0	17.5	17.7	37.4	55.0
5	TSS	mg/L	18.0	7.0	42.0	2.0	16.0	28.0	20.0	18.0	23.0	52.0	23.0	25.0	29.0	44.0	48.0
6	TDS	mg/L	7.80	15.20	9.20	17.20	9.50	7.80	37.10	35.60	8.20	8.00	7.30	7.90	8.10	12.30	26.50
7	THC	mg/L	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
8	COD	mg/L	7.15	7.353	8.29	6.08	9.22	6.127	8.34	7.57	8.02	10.078	5.36	7.54	7.18	8.22	7.05
9	DO	mg/L	6.80	6.80	5.90	5.30	6.00	5.50	7.10	5.00	5.20	6.40	5.80	6.20	6.00	5.50	6.30
10	BOD5	mg/L	2.30	2.60	1.90	2.10	2.50	2.90	1.50	2.00	2.20	2.00	2.90	2.30	1.50	2.40	2.80
11	Salinity as Cl	mg/L	3.97	6.18	5.08	11.12	6.95	5.08	14.52	16.18	5.63	3.97	5.08	4.04	5.29	4.48	12.78
12	Odour	TON	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
13	Nitrite	mg/L	0.014	0.013	0.001	<0.001	<0.001	<0.001	0.011	0.006	0.010	0.005	0.003	<0.001	0.004	0.002	0.002
14	Colour	mg/L	7	10	9	17	14	26	8	10	10	15	12	7	5	19	17
15	Alkalinity	mg/L	36.00	40.00	42.00	40.00	38.00	40.00	44.00	38.00	42.00	42.00	46.00	36.00	50.00	44.00	44.00
16	Oil & Grease	mg/L	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
17	Nitrate	mg/L	0.021	0.017	0.004	0.004	0.004	0.004	0.018	0.019	0.029	0.010	0.017	0.004	0.009	0.007	0.008
18	Phenols	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
19	Sulphate	mg/L	1.46	1.79	0.85	1.16	1.10	0.49	1.46	0.85	0.49	0.87	0.49	1.88	0.49	0.83	2.49
20	Ammonia	mg/L	0.230	0.083	0.181	0.209	0.202	0.202	0.216	0.209	0.321	0.181	0.125	0.216	0.251	0.181	0.146

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S/ N	PARAMET ER	UNI T	SW 1	SW 2	SW 4	SW5	SW6	SW7	SW 9	SW1 0	SW1 1	SW1 2	SW1 3	SW1 6	SW1 7	SWCTR L 1	SWCTR L 2
21	Phosphate	mg/L	0.03 7	0.01 5	0.02 1	0.015	0.024	0.032	0.02 9	0.02 4	0.03 3	0.021	0.04 0	0.053	0.03 3	0.040	0.017
22	reactive silica	mg/L	0.51	0.70	0.56	0.54	0.34	0.85	0.23	0.46	0.38	0.62	0.59	1.12	0.79	0.94	0.52

Appendix 4.6.3c:

Measurements of metals in surface water in Enwhe Field during the wet season

S/ N	PARAMETER	UNIT	SW 1	SW 2	SW 3	SW 4	SW 5	SW 6	SW 7	SW 8	SW 9	SW 10	SW 11	SW 12	SW 13	SW 14	SW 15	SW 16	SW 17	SWC TRL 1	SWC TRL 2
1	Na	mg/L	2.047	22.381	1.098	1.148	1.681	1.121	4.681	8.063	5.868	6.452	2.148	3.068	2.008	1.053	2.063	0.421	2.088	5.257	5.681
2	K	mg/L	0.925	5.903	0.945	0.875	0.501	0.912	2.899	0.935	0.418	1.254	0.917	0.598	0.934	0.687	0.543	0.922	0.937	2.840	1.806
3	Ca	mg/L	0.659	0.566	0.324	0.651	0.221	0.339	0.417	0.790	0.529	0.387	0.313	0.320	0.703	0.281	0.222	0.320	0.249	0.309	0.347
4	Mg	mg/L	0.409	0.362	0.264	0.415	0.255	0.311	0.278	0.393	0.306	0.244	0.252	0.241	0.522	0.225	0.207	0.272	0.255	0.292	0.230
5	Mn	mg/L	0.053	0.187	0.082	0.124	0.091	0.136	0.108	0.057	0.112	0.083	0.144	0.077	0.053	0.034	0.058	0.092	0.104	0.068	0.060
6	Fe	mg/L	0.821	7.244	0.532	1.606	1.657	2.316	2.31	0.723	3.027	1.622	3.32	1.281	0.524	0.305	1.283	0.672	0.775	0.426	0.625
7	Cd	mg/L	<0.001	<0.001	<0.001	0.003	0.006	<0.001	<0.001	0.008	<0.001	<0.001	0.005	<0.001	<0.001	<0.001	0.004	<0.001	<0.001	<0.001	<0.001
8	Cr	mg/L	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
9	Ni	mg/L	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
10	V	mg/L	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
11	Pb	mg/L	0.021	0.034	0.005	0.007	0.015	0.028	0.016	0.013	0.026	0.015	0.042	0.013	0.009	0.029	0.044	0.033	0.069	0.035	0.025
12	Zn	mg/L	0.300	2.228	0.196	0.343	0.425	0.527	0.114	0.397	0.982	0.450	0.648	0.511	0.293	0.367	0.352	0.341	0.146	0.241	0.305
13	Hg	mg/L	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02

Appendix 4.6.3d:

Measurements of metals in surface water in Enwhe Field during the dry season

S/ N	PARAME TER	UNI T	SW1	SW2	SW4	SW5	SW6	SW7	SW9	SW1 0	SW1 1	SW1 2	SW1 3	SW1 6	SW1 7	SWCT RL 1	SWCT RL 2
1	Na	mg/ L	1.71 6	1.62 8	1.74 6	1.18 7	1.44 5	1.26 8	1.00 3	1.18 2	1.26 7	1.21 9	1.33 9	1.45 0	1.52 4	1.727	1.717
2	K	mg/ L	0.16 4	0.23 9	0.40 4	0.38 8	0.87 5	0.20 3	0.31 6	0.54 7	0.99 7	0.95 1	1.00 3	0.76 9	0.17 0	0.204	0.882
3	Ca	mg/ L	0.36 5	0.31 4	0.36 7	0.20 6	0.31 0	0.22 6	0.31 9	0.32 6	0.38 1	0.27 0	0.32 3	0.27 0	0.31 7	0.235	0.217
4	Mg	mg/ L	0.11 7	0.11 1	0.11 3	0.10 8	0.11 8	0.14 2	0.24 1	0.14 3	0.11 5	0.12 9	0.12 9	0.23 3	0.13 3	0.294	0.108
5	Mn	mg/ L	0.03 3	0.05 0	0.03 3	0.04 4	0.04 3	0.04 3	0.02 0	0.02 0	0.08 3	0.08 0	0.06 4	0.01 5	0.04 7	0.034	0.042
6	Fe	mg/ L	0.66 9	0.53 9	0.66 9	0.53 9	0.92 8	0.66 9	0.53 9	0.92 8	0.66 9	0.79 8	0.92 8	0.53 9	1.05 8	0.798	0.928
7	Cd	mg/ L	<0.0 01	<0.0 01	0.00 3	0.00 6	<0.0 01	<0.0 01	<0.0 01	<0.0 01	0.00 5	<0.0 01	<0.0 01	<0.0 01	<0.0 01	<0.001	<0.001
8	Cr	mg/ L	<0.0 05	<0.0 05	<0.0 05	<0.0 05	<0.0 05	<0.0 05	<0.0 05	<0.0 05	<0.0 05	<0.0 05	<0.0 05	<0.0 05	<0.0 05	<0.005	<0.005
9	Ni	mg/ L	<0.0 05	<0.0 05	<0.0 05	<0.0 05	<0.0 05	<0.0 05	<0.0 05	<0.0 05	<0.0 05	<0.0 05	<0.0 05	<0.0 05	<0.0 05	<0.005	<0.005
10	V	mg/ L	<0.0 05	<0.0 05	<0.0 05	<0.0 05	<0.0 05	<0.0 05	<0.0 05	<0.0 05	<0.0 05	<0.0 05	<0.0 05	<0.0 05	<0.0 05	<0.005	<0.005
11	Pb	mg/ L	0.01 4	0.01 2	0.01 0	0.01 4	0.01 3	0.02 8	0.01 9	0.01 9	0.02 6	0.03 1	0.04 4	0.04 0	0.04 9	0.040	0.035
12	Zn	mg/ L	0.29 3	0.29 4	0.28 9	0.28 9	0.28 5	0.29 5	0.28 7	0.28 5	0.31 6	0.30 8	0.30 8	0.31 5	0.36 9	0.2919	0.2906
13	Hg	mg/ L	<0.0 2	<0.0 2	<0.0 2	<0.0 2	<0.0 2	<0.0 2	<0.0 2	<0.0 2	<0.0 2	<0.0 2	<0.0 2	<0.0 2	<0.0 2	<0.02	<0.02

Appendix 4.6.3e:

Microbiological measurements in surface water in Enwhe Field during the wet season

S/N	PARAMETER	UNIT	S W 1	S W 2	S W 3	S W 4	S W 5	S W 6	S W 7	S W 8	S W 9	SW 10	SW 11	SW 12	SW 13	SW 14	SW 15	SW 16	SW 17	SWC TRL 1	SWC TRL 2
1	Coliform Count	MPN/100ml	5	11	13	6	12	7	10	15	5	11	9	4	7	3	12	9	3	11	9
2	HUB	cfu/ml X 10 ²	0.13	0.21	0.37	0.29	0.26	0.26	0.36	0.53	0.75	0.72	0.26	0.26	0.34	0.42	0.62	0.25	0.43	0.33	0.10
3	HUF	cfu/ml X 10 ²	0.05	0.16	NIL	NIL	0.17	NIL	NIL	NIL	0.03	0.05	0.03	NIL	NIL	NIL	NIL	0.03	0.07	NIL	NIL
4	THB	cfu/ml X 10 ³	0.41	0.29	0.97	0.83	0.52	0.76	0.51	0.38	0.75	0.45	0.36	0.50	0.91	0.62	0.85	0.28	0.67	0.48	0.60
5	THF	cfu/ml X 10 ²	0.08	0.03	NIL	NIL	0.08	0.04	NIL	0.08	0.25	0.25	NIL	0.03	0.05	NIL	NIL	NIL	0.07	0.05	NIL

Appendix 4.6.3f:

Microbiological measurements in surface water in Enwhe Field during the dry season

S/N	PARAMETER	UNIT	SW 1	SW 2	SW 4	SW 5	SW 6	SW 7	SW 9	SW1 0	SW1 1	SW1 2	SW1 3	SW1 6	SW1 7	SWCTR L 1	SWCTR L 2
1	Coliform Count	MPN/100ml	2	13	8	3	2	5	8	3	13	2	2	3	2	5	3
2	HUB	cfu/ml X 10 ²	0.10	0.13	0.016	0.11	0.21	0.24	0.18	0.22	0.29	0.31	0.12	0.23	0.12	0.16	0.10
3	HUF	cfu/ml X 10 ²	NIL	NIL	0.08	NIL	NIL	NIL	NIL	0.09	NIL	0.34	NIL	0.08	0.05	NIL	NIL
4	THB	cfu/ml X 10 ³	0.34	0.40	0.23	0.30	0.45	0.45	0.15	0.37	0.29	0.29	0.75	0.26	0.23	0.19	0.26
5	THF	cfu/ml X 10 ²	0.07	0.02	0.07	0.09	0.07	NIL	0.08	0.71	0.14	0.08	0.03	0.03	0.05	0.07	0.07

Appendix 4.6.4a:

Measurements of physicochemical parameters in sediment in Enwhe Field during the wet season

FIELD CODE	pH	Redox Potential (mV)	EC (µS/cm)	TOC (O/O)	O & G (ppm)	NH4+ (mg/kg)	NO3- (mg/kg)	SO4 ²⁻ (mg/kg)	TOTAL PHOSPHOROUS (mg/kg)	TOTAL NITROGEN (O/O)	THC (mg/kg)	Cl- (mg/kg)	% Sand	% Silt	% Clay	Texture
SD/1	4.54	125.80	34.30	0.13	6.8	0.333	1.413	3.13	1.33	0.0014	2.8	12.20	65.00	10.00	25.00	SANDY CLAY LOAM
SD/2	6.71	93.10	130.20	0.16	5.5	0.278	1.373	15.43	1.15	0.0018	3.0	45.40	45.10	32.40	22.50	SANDY LOAM
SD/3	5.22	108.40	72.10	0.10	6.3	0.356	0.804	4.11	0.94	0.0031	2.5	24.90	53.00	36.00	11.00	SANDY LOAM
SD/4	4.71	122.80	21.30	0.16	7.3	0.254	2.952	3.30	0.46	0.0026	2.6	8.00	24.00	24.00	52.00	LOAM
SD/5	4.98	116.60	34.80	0.25	5.8	0.310	1.052	4.28	0.94	0.0023	2.9	12.30	65.00	30.00	15.00	SANDY LOAM
SD/6	5.98	103.50	81.50	0.13	6.2	0.323	1.706	3.57	2.16	0.0016	1.8	27.00	74.10	74.00	18.50	SANDY LOAM
SD/7	5.13	107.80	76.50	0.17	4.2	0.380	2.104	2.20	1.52	0.0019	2.8	12.20	24.00	53.00	23.00	SILTY LOAM
SD/8	6.80	93.60	79.00	0.25	8.7	0.273	5.371	3.94	0.94	0.0015	3.1	12.50	72.00	14.00	14.00	SANDY LOAM
SD/9	6.71	92.80	123.00	0.24	6.4	0.373	2.467	28.00	1.29	0.0020	3.4	34.10	70.00	17.00	13.00	SANDY LOAM
SD/10	4.72	102.90	81.30	0.13	7.4	0.281	2.185	7.72	1.27	0.0032	3.1	23.50	65.00	18.00	17.00	SANDY LOAM
SD/11	6.75	92.40	121.10	0.14	6.2	0.354	2.535	9.50	0.51	0.0035	2.0	47.40	87.00	7.00	6.00	LOAM SAND
SD/12	5.11	104.60	39.20	0.05	7.4	0.154	0.522	3.63	0.49	0.0014	2.5	11.90	43.10	44.70	13.80	SANDY LOAM
SD/13	5.21	104.90	30.20	0.13	7.8	0.342	2.663	7.86	0.77	0.0019	3.8	7.70	46.20	4.30	50.50	SAND CLAY LOAM
SD/14	4.21	115.20	81.50	0.16	5.6	0.129	0.934	4.50	0.78	0.0017	1.8	24.20	64.20	21.80	14.00	SANDY LOAM

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FIELD CODE	pH	Redox Potential (mV)	EC (µS/cm)	TOC (O/O)	O & G (ppm)	NH4+ (mg/kg)	NO3- (mg/kg)	SO4²⁻ (mg/kg)	TOTAL PHOSPHOROUS (mg/kg)	TOTAL NITROGEN (O/O)	THC (mg/kg)	Cl- (mg/kg)	% Sand	% Silt	% Clay	Texture
SD/15	5.70	101.70	58.40	0.12	8.5	0.325	0.759	7.86	1.88	0.0041	3.9	15.30	54.60	25.60	19.80	SANDY LOAM
SD/16	5.50	102.10	32.80	0.14	6.3	0.325	0.398	6.37	1.67	0.0025	3.2	12.60	64.00	12.00	24.00	SANDY CLAY LOAM
SD/SD17	4.81	111.40	34.00	0.21	5.2	0.443	0.438	3.07	0.92	0.0040	3.6	11.00	70.00	14.00	16.00	SANDY LOAM
SD/C1	6.01	97.30	108.30	0.12	6.0	0.134	5.347	7.82	0.45	0.0014	1.8	29.20	63.00	21.00	16.00	SANDY LOAM
SD/C2	5.98	100.50	97.90	0.19	6.4	0.262	0.844	7.05	0.96	0.0023	1.8	35.80	72.00	19.00	9.00	SANDY LOAM

Appendix 4.6.4b:

Measurements of physicochemical parameters in sediment in Enwhe Field during the dry season

FIELD CODE	pH	Red ox Potential (mV)	EC (uS/cm)	TOC (O/O)	O & G (ppm)	NH4 + (mg/kg)	NO3 - (mg/kg)	SO4 2- (mg/kg)	TP (mg/kg)	TN (O/O)	THC (mg/kg)	Cl- (mg/kg)	% Sand	% Silt	% Clay	Texture
SD/1	5.92	63.60	22.09	0.18	5.2	0.191	0.253	1.64	1.43	0.0018	1.5	17.56	85.23	7.73	7.04	LOAMY SAND
SD/2	6.78	21.10	105.04	0.37	7.60	0.160	0.829	14.93	1.08	0.0018	1.2	31.16	78.55	10.80	10.65	SANDY LOAM
SD/4	5.71	79.40	56.80	0.43	5.9	0.199	0.861	3.03	0.74	0.0015	1.9	18.84	75.32	5.60	19.08	SANDY LOAM
SD/5	5.43	85.80	23.80	0.43	5.7	0.281	0.690	1.40	0.84	0.0017	2.2	8.40	87.18	6.41	6.41	SANDY LOAM
SD/6	5.80	57.20	25.25	0.36	3.3	0.186	0.206	1.89	0.65	0.0019	1.2	11.12	82.55	6.18	11.27	SANDY LOAM
SD/7	6.61	27.80	87.01	0.43	4.3	0.284	0.497	0.97	2.16	0.0011	2.0	21.40	82.88	7.68	9.44	SANDY LOAM
SD/9	5.58	89.40	70.09	0.34	4.4	0.253	1.267	1.97	1.52	0.0014	1.4	18.12	87.03	6.19	6.78	SANDY LOAM
SD/10	5.18	61.70	59.73	0.07	3.5	0.417	2.721	1.51	0.89	0.0026	1.8	14.12	80.00	5.18	14.82	SANDY LOAM
SD/11	6.03	29.00	117.23	0.27	5.4	0.157	0.172	3.57	0.72	0.0041	1.0	27.68	82.32	7.75	9.93	SANDY LOAM
SD/12	5.20	85.00	50.55	0.29	6.4	0.350	1.553	5.05	1.54	0.0023	1.9	21.12	84.97	6.50	8.53	SANDY LOAM
SD/13	5.25	61.00	114.32	0.09	5.6	0.270	2.477	9.21	1.54	0.0017	2.4	41.12	83.00	6.50	10.50	SANDY LOAM
SD/16	5.55	64.90	26.58	0.25	6.4	0.163	0.265	3.06	0.12	0.0020	1.7	15.02	78.76	11.69	9.55	LOAMY SAND
SD/17	5.44	68.20	24.43	0.38	4.6	0.270	1.860	1.92	0.71	0.0015	2.1	7.12	80.17	11.68	8.15	LOAMY SAND

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FIELD CODE	pH	Red ox Potential (mV)	EC (uS/cm)	TOC (O/O)	O & G (ppm)	NH4 + (mg/kg)	NO3 - (mg/kg)	SO4 2- (mg/kg)	TP (mg/kg)	TN (O/O)	THC (mg/kg)	Cl- (mg/kg)	% Sand	% Silt	% Clay	Texture
SD/C1	4.47	132.40	75.03	0.07	4.1	0.067	0.484	6.62	0.57	0.0066	2.3	19.34	92.60	2.60	4.80	SAND
SD/C2	5.16	63.60	50.13	0.10	3.7	0.269	0.863	1.36	0.99	0.0018	2.2	10.48	85.23	7.73	7.04	LOAMY SAND

Appendix 4.6.4c:

Measurements of exchangeable cations in sediments in Enwhe Field during the wet season

S/N	FIELD CODE	Na (meq/100g)	K (meq/100g)	Ca (meq/100g)	Mg (meq/100g)
1	SD/1	38.042	13.056	61.108	5.438
2	SD/2	18.722	20.013	14.297	17.242
3	SD/3	36.110	23.356	19.799	19.389
4	SD/4	27.416	5.519	13.706	15.090
5	SD/5	16.433	9.577	19.942	21.538
6	SD/6	88.679	53.239	13.627	11.878
7	SD/7	17.510	12.469	9.025	14.201
8	SD/8	26.740	15.689	13.340	14.926
9	SD/9	67.263	17.978	33.718	13.503
10	SD/10	55.091	30.381	22.389	25.221
11	SD/11	20.789	13.471	10.792	9.881
12	SD/12	19.703	11.853	9.498	8.910
13	SD/13	37.734	22.672	18.153	17.023
14	SD/14	11.257	6.786	5.444	5.109
15	SD/15	15.245	3.382	2.722	2.556
16	SD/16	10.637	6.413	9.540	4.830

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S/N	FIELD CODE	Na (meq/100g)	K (meq/100g)	Ca (meq/100g)	Mg (meq/100g)
17	SD/SD17	14.645	3.022	37.479	19.389
18	SD/C1	15.399	9.271	17.787	14.027
19	SD/C2	13.679	8.239	25.664	2.218

Appendix 4.6.4d:

Measurements of exchangeable cations in sediments in Enwhe Field during the dry season

S/N	FIELD CODE	Na (meq/100g)	K (meq/100g)	Ca (meq/100g)	Mg (meq/100g)
1	SD/1	33.251	12.635	52.860	4.958
2	SD/2	15.078	18.459	13.674	14.840
3	SD/4	32.634	21.257	18.280	16.636
4	SD/5	24.356	6.326	13.179	13.038
5	SD/6	15.162	9.723	18.400	16.435
6	SD/7	76.639	46.272	13.113	10.349
7	SD/9	18.064	12.144	9.261	12.294
8	SD/10	20.790	14.839	12.873	9.900
9	SD/11	53.712	16.756	29.931	11.710
10	SD/12	45.523	27.138	20.448	21.518
11	SD/13	19.809	12.983	10.740	4.678
12	SD/16	18.900	11.629	9.657	7.864
13	SD/17	30.993	20.684	16.902	12.656
14	SD/C1	10.829	7.386	6.263	4.683
15	SD/C2	15.168	4.538	3.984	1.546

Appendix 4.6.4e:

Measurements of metals in sediments in Enwhe Field during the wet season

S/N	FIELD CODE	Fe (mg/kg)	Cu (mg/kg)	Zn (mg/kg)	V (mg/kg)	Pb (mg/kg)	Cd (mg/kg)	Ni (mg/kg)	Cr (mg/kg)
1	SD/1	5444.01	3.320	31.495	<0.05	5.228	0.700	4.116	0.233
2	SD/2	3190.55	1.200	38.910	<0.05	2.047	0.566	3.003	0.823
3	SD/3	7593.77	1.072	33.977	<0.05	3.395	0.688	4.106	1.414
4	SD/4	5798.33	1.377	35.838	<0.05	6.727	0.796	4.845	1.491
5	SD/5	6355.60	1.478	41.226	<0.05	2.004	0.881	6.010	0.479
6	SD/6	6823.71	3.409	43.648	<0.05	2.036	0.718	7.844	0.392
7	SD/7	4346.78	2.036	40.257	<0.05	5.458	0.495	6.083	0.221
8	SD/8	7102.85	3.022	44.110	<0.05	3.008	0.797	4.980	0.138
9	SD/9	5548.69	1.459	41.212	<0.05	7.593	0.823	3.939	0.141
10	SD/10	4539.79	1.395	45.093	<0.05	4.072	0.689	3.793	0.102
11	SD/11	7054.62	0.620	29.123	<0.05	4.935	0.817	4.677	0.734
12	SD/12	6456.67	0.507	32.849	<0.05	3.135	0.620	3.793	0.088
13	SD/13	7298.53	0.903	43.093	<0.05	2.858	0.505	4.376	0.447
14	SD/14	6741.39	1.498	38.329	<0.05	2.999	0.978	5.082	0.204
15	SD/15	7354.50	1.320	41.714	<0.05	4.376	0.921	3.430	0.519
16	SD/16	4309.09	2.025	39.198	<0.05	1.572	0.592	5.064	0.861
17	SD/SD17	4920.67	0.605	37.525	<0.05	4.515	0.406	4.067	0.773
18	SD/C1	6434.60	1.030	33.756	<0.05	5.714	0.723	5.116	0.554
19	SD/C2	6154.92	0.653	30.702	<0.05	7.153	0.808	4.806	0.954

Appendix 4.6.4f:

Measurements of metals in sediments in Enwhe Field during the dry season

S/N	FIELD CODE	Fe (mg/kg)	Cu (mg/kg)	Zn (mg/kg)	V (mg/kg)	Pb (mg/kg)	Cd (mg/kg)	Ni (mg/kg)	Cr (mg/kg)
1	SD/1	5147.30	1.497	23.580	<0.05	5.726	0.561	4.844	0.075
2	SD/2	4277.60	1.413	22.264	<0.05	6.116	0.487	3.477	0.159
3	SD/4	4499.44	3.176	50.033	<0.05	6.840	0.667	5.897	0.192
4	SD/5	5996.81	3.291	51.831	<0.05	5.278	0.656	4.475	0.180
5	SD/6	5809.86	2.803	44.154	<0.05	7.545	0.449	4.633	0.137
6	SD/7	4833.44	6.874	48.269	<0.05	8.766	0.680	5.213	0.080
7	SD/9	4680.78	1.919	30.226	<0.05	8.638	0.468	4.633	0.070
8	SD/10	4263.70	5.077	36.872	<0.05	8.788	0.517	5.369	0.126
9	SD/11	4595.09	2.821	44.439	<0.05	7.268	0.734	6.973	0.110
10	SD/12	5376.74	1.465	23.075	<0.05	6.766	0.589	6.708	0.082
11	SD/13	5006.04	1.636	25.773	<0.05	8.596	0.509	5.208	0.092
12	SD/16	4931.68	4.495	30.805	<0.05	7.953	0.529	4.434	0.110
13	SD/17	4528.20	4.139	32.711	<0.05	5.696	0.629	3.137	0.208
14	SD/C1	5372.06	3.981	39.973	<0.05	2.130	0.549	5.279	0.142
15	SD/C2	5146.23	2.341	45.189	<0.05	3.128	0.511	5.239	0.225

Appendix 4.6.4g:

Microbiological measurements in sediments in Enwhe Field during the wet season

S/N	SAMPLE CODE	(THB) X 104 (cfu/g)	(THF) X 103 (cfu/g)	(HUB) X 103 (cfu/g)	(HUF) X 102 (cfu/g)
1	SD/1	1.70	1.00	0.52	NIL
2	SD/2	3.80	2.00	0.25	0.12
3	SD/3	1.20	0.75	0.30	0.25
4	SD/4	3.74	0.67	0.55	0.04
5	SD/5	1.01	0.24	0.35	0.05
6	SD/6	0.75	0.35	0.52	0.08
7	SD/7	1.23	0.43	0.49	0.12
8	SD/8	3.75	0.32	0.59	0.29
9	SD/9	5.02	0.65	0.57	0.08
10	SD/10	1.61	0.50	0.29	0.18
11	SD/11	4.85	0.78	0.91	0.02
12	SD/12	2.50	0.22	0.37	0.15
13	SD/13	1.76	0.43	0.98	0.05
14	SD/14	4.60	0.55	0.52	0.05
15	SD/15	0.97	NIL	0.40	0.05
16	SD/16	3.50	0.25	0.40	0.05
17	SD/SD17	1.30	0.50	0.26	NIL
18	SD/C1	1.48	0.27	0.14	0.04
19	SD/C2	4.18	1.59	0.27	0.04

Appendix 4.6.4h:

Microbiological measurements in sediments in Enwhe Field during the dry season

S/N	SAMPLE CODE	(THB) X 10 ⁴ (cfu/g)	(THF) X 10 ³ (cfu/g)	(HUB) X 10 ³ (cfu/g)	(HUF) X 10 ² (cfu/g)
1	SD/1	1.30	0.39	0.83	0.09
2	SD/2	2.10	0.74	0.60	0.04
3	SD/4	0.96	0.78	0.31	0.13
4	SD/5	0.32	0.49	0.70	0.09
5	SD/6	0.56	0.11	0.73	0.05
6	SD/7	3.74	0.91	0.11	0.09
7	SD/9	1.12	0.45	0.17	0.03
8	SD/10	3.55	0.68	0.93	0.09
9	SD/11	2.33	0.51	0.28	0.04
10	SD/12	1.40	0.59	0.92	0.08
11	SD/13	1.65	0.52	0.71	0.06
12	SD/16	1.35	0.24	0.32	0.05
13	SD/17	1.65	0.21	0.34	0.08
14	SD/C1	0.88	0.12	0.14	0.10
15	SD/C2	3.44	0.39	0.14	0.05

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Appendix 4.6.8a:

Measurements of physicochemical parameters groundwater in Enwhe Field during the wet season

S/N	PARAMETER	UNIT	BH1	BH2	BH3	BH4	BH5	BH6	BH7	BH8	BH9	BH10	BH11	BH CTRL 1	BH CTRL 2
1	pH		5.30	4.80	5.13	5.15	6.19	6.00	6.50	5.51	5.40	5.17	6.32	6.31	6.57
2	Temp	0C	30.40	29.80	27.50	28.30	30.30	31.10	28.70	25.40	27.50	27.60	28.20	25.50	20.10
3	Redox Potential	mV	92.50	106.70	77.30	76.80	32.40	34.60	28.50	71.90	71.40	76.60	13.50	13.70	10.50
4	Electrical Conductivity	µS/cm	17.20	13.70	13.64	9.73	47.00	312.00	18.50	14.52	15.50	16.40	30.10	53.10	40.20
5	Turbidity	NTU	34740.0	33540.0	41680.0	39350.0	371.6	51400.0	30350.0	103500.0	20840.0	50670.0	28350.0	81.5	77100.0
6	TSS	mg/L	57500.0	31200.0	30600.0	25200.0	36000.0	55000.0	208.0	49500.0	50000.0	160000.0	9000.0	24000.0	75000.0
7	TDS	mg/L	8.60	6.90	6.80	4.80	23.50	155.80	9.30	7.20	7.80	8.30	15.1	26.60	20.10
8	THC	mg/L	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
9	COD	mg/L	7.76	8.56	8.56	9.16	12.76	5.36	6.34	9.16	8.76	8.56	9.36	6.43	9.22
10	DO	mg/L	5.50	4.00	3.80	6.90	0.40	0.30	1.30	4.60	1.70	5.80	1.10	3.50	1.90
11	BOD5	mg/L	1.40	0.80	1.50	2.90	2.50	3.20	2.10	1.30	2.00	2.40	2.50	1.00	2.30
12	Salinity as Cl	mg/L	5.12	2.00	4.35	1.56	5.57	74.15	2.45	6.46	4.68	2.00	2.45	6.01	5.69
13	Odour	TON	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
14	Nitrite	mg/L	0.015	0.076	0.066	0.094	0.038	0.014	0.019	0.014	0.075	0.051	0.073	0.045	0.035
15	Colour	mg/L	17	27	95	21	16	45	53	39	31	42	47	32	39
16	Alkalinity	mg/L	18.00	14.30	15.30	17.60	24.60	23.70	29.00	12.20	12.10	12.10	22.00	29.40	23.00
17	Oil & Grease	mg/L	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
18	Nitrate	mg/L	0.284	0.026	0.073	0.042	5.429	0.090	0.064	0.600	0.216	1.197	2.751	0.161	5.572
19	Phenols	mg/L	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
20	Sulphate	mg/L	11.14	1.15	1.07	3.63	3.02	74.82	1.16	2.41	1.71	1.59	5.15	8.18	2.47
21	Ammonia	mg/L	1.738	3.327	1.705	1.599	1.585	4.069	1.469	1.328	15.782	16.955	2.464	1.469	1.422
22	Phosphate	mg/L	0.195	0.017	0.003	0.119	4.857	0.026	0.026	0.021	0.028	0.220	0.452	0.026	0.302
23	reactive silica	mg/L	1.05	0.98	1.09	1.00	1.35	3.71	2.31	4.48	2.53	2.86	3.14	2.99	3.23

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Appendix 4.6.8b:

Measurements of physicochemical parameters in groundwater in Enwhe Field during the dry season

S/N	PARAMETER	UNIT	BH1	BH2	BH3	BH5	BH6	BH7	BH8	BH9	BH10	BH11	BH CTRL 1	BH CTRL 2
1	pH		7.10	6.22	5.60	6.50	6.50	6.70	5.40	5.90	5.72	7.01	6.60	6.50
2	Temp	0C	26.70	26.10	29.30	28.30	30.10	25.90	33.10	25.40	25.00	26.70	27.30	26.70
3	Redox Potential	mV	-13.20	35.70	58.50	36.90	35.80	32.80	56.30	50.50	53.60	-6.40	31.40	35.80
4	Electrical Conductivity	µS/cm	98.90	30.80	6.50	53.00	15.00	34.80	14.60	9.60	18.20	132.30	15.80	18.20
5	Turbidity	NTU	13.7	15.3	21.0	2520.0	49.1	70.0	133.0	116.0	93.0	10.0	25.3	54.4
6	TSS	mg/L	12.0	19.0	15.0	2710.0	33.0	76.0	149.0	85.0	108.0	17.0	32.0	43.0
7	TDS	mg/L	49.50	15.40	3.30	26.50	7.50	17.40	7.30	4.80	9.20	66.20	7.90	9.60
8	THC	mg/L	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
9	COD	mg/L	5.05	9.12	7.25	9.27	14.55	13.90	10.27	8.29	8.52	10.65	9.75	8.43
10	DO	mg/L	4.70	5.30	4.80	4.90	5.60	4.50	5.30	3.90	4.60	3.90	5.00	4.40
11	BOD5	mg/L	0.90	0.70	1.10	0.90	1.40	0.70	1.60	1.10	2.00	1.50	0.80	1.40
12	Salinity as Cl	mg/L	7.29	5.63	1.08	6.18	3.28	5.08	3.84	2.63	2.82	43.97	3.97	5.56
13	Odour	TON	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
14	Nitrite	mg/L	<0.001	0.004	0.008	0.033	0.001	0.004	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
15	Colour	mg/L	9	11	15	4	19	14	6	9	13	8	12	15
16	Alkalinity	mg/L	32.90	23.10	16.80	21.90	20.60	20.30	12.90	14.40	11.60	29.70	26.30	21.00
17	Oil & Grease	mg/L	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
18	Nitrate	mg/L	0.009	0.010	0.011	0.289	0.018	0.007	0.010	0.010	0.012	0.008	0.004	0.010
19	Phenols	mg/L	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
20	Sulphate	mg/L	1.44	0.97	0.90	1.91	2.41	0.84	0.91	2.32	2.99	7.79	0.75	0.41
21	Ammonia	mg/L	<0.001	<0.001	<0.001	0.340	0.056	<0.001	0.067	0.085	<0.001	<0.001	<0.001	0.038
22	Phosphate	mg/L	0.019	0.012	0.018	0.057	0.013	0.020	0.011	0.009	0.062	0.020	0.032	0.034
23	reactive silica	mg/L	0.17	0.25	0.16	0.15	0.36	0.35	0.24	0.35	0.24	0.15	0.13	0.19

Appendix 4.6.8c:

Measurements of metals in groundwater in Enwhe Field during the wet season

S/N	PARAMETER	UNIT	BH1	BH2	BH3	BH4	BH5	BH6	BH7	BH8	BH9	BH10	BH11	BH CTRL 1	BH CTRL 2
1	Na	mg/L	3.272	2.349	2.283	0.960	7.351	56.396	2.644	2.162	2.357	2.074	4.816	5.767	5.839
2	K	mg/L	0.724	0.973	0.355	0.266	1.164	11.473	0.971	0.547	0.689	0.764	0.897	2.951	1.840
3	Ca	mg/L	0.102	0.035	0.091	0.090	0.951	4.356	0.268	0.178	0.121	0.350	0.746	0.925	0.579
4	Mg	mg/L	0.068	0.024	0.016	0.043	0.319	1.036	0.291	0.276	0.268	0.336	0.364	0.818	0.844
5	Mn	mg/L	0.006	0.003	0.003	0.008	0.010	0.011	0.005	0.006	0.003	0.010	0.012	0.006	0.009
6	Fe	mg/L	0.754	0.938	0.990	0.933	0.551	0.820	0.336	0.580	0.510	0.730	0.573	0.626	0.752
7	Cd	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
8	Cr	mg/L	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
9	Ni	mg/L	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
10	V	mg/L	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
11	Pb	mg/L	0.007	0.002	0.009	<0.001	<0.001	0.002	0.007	0.005	0.003	<0.001	0.002	<0.001	<0.001
12	Zn	mg/L	0.257	0.173	0.156	0.254	0.191	0.140	0.173	0.250	0.160	0.223	0.141	0.130	0.152
13	Hg	mg/L	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02

Appendix 4.6.8d:

Measurements of metals in groundwater in Enwhe Field during the dry season

S/N	PARAMETER	UNIT	BH1	BH2	BH3	BH5	BH6	BH7	BH8	BH9	BH10	BH11	BH CTRL 1	BH CTRL 2
1	Na	mg/L	14.51	2.93	1.94	4.12	1.57	1.91	1.99	1.72	2.85	25.90	2.41	1.58
2	K	mg/L	3.545	0.571	0.21	0.426	0.886	0.811	0.547	0.827	0.282	4.437	0.597	0.337
3	Ca	mg/L	0.178	0.304	0.060	0.145	0.693	0.166	0.321	0.359	0.340	1.195	0.692	0.721
4	Mg	mg/L	0.091	0.213	0.036	0.053	0.406	0.070	0.056	0.164	0.585	0.977	0.155	0.245
5	Mn	mg/L	0.006	0.009	0.007	0.006	0.006	0.011	0.008	0.010	0.009	0.012	0.010	0.007
6	Fe	mg/L	0.662	0.610	0.299	0.253	0.873	0.359	0.460	0.514	0.666	0.272	0.242	0.384
7	Cd	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
8	Cr	mg/L	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
9	Ni	mg/L	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
10	V	mg/L	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
11	Pb	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
12	Zn	mg/L	0.170	0.167	0.181	0.180	0.216	0.203	0.192	0.212	0.204	0.204	0.192	0.214
13	Hg	mg/L	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02

Appendix 4.6.8e:

Microbiological measurements in groundwater in Enwhe Field during the wet season

S/N	PARAMETER	UNIT	BH1	BH2	BH3	BH4	BH5	BH6	BH7	BH8	BH9	BH10	BH11	BH CTRL 1	BH CTRL 2
1	Coliform Count	MPN/100ml	4	9	3	5	2	4	5	2	2	8	5	2	3
2	HUB	cfu/ml X 102	2.7	1.2	0.9	1.1	2.3	1.2	1.3	1.7	0.8	1.2	1.5	1	0.6
3	HUF	cfu/ml X 102	1.5	0.3	NIL	NIL	0.3	0.25	0.46	NIL	0.33	0.18	0.25	NIL	NIL
4	THB	cfu/ml X 103	3.0	2.5	4.8	7	4.2	4.7	5.6	3.8	7.1	5.4	6.8	4.7	2.4
5	THF	cfu/ml X 103	0.75	0.14	0.26	NIL	0.26	NIL	0.48	NIL	NIL	0.38	0.52	NIL	NIL

Appendix 4.6.8f:

Microbiological measurements in ground in Enwhe Field during the dry season

UNIT	BH1	BH2	BH3	BH5	BH6	BH7	BH8	BH9	BH10	BH11	BH CTRL 1	BH CTRL 2
MPN/100ml	19	10	8	5	3	13	8	11	11	8	4	5
cfu/ml X 102	1.02	1.48	1.51	1.35	1.18	0.57	1.65	1.36	2.25	0.96	1.85	1.00
cfu/ml X 102	0.16	0.21	0.13	NIL	0.16	0.20	0.12	NIL	NIL	0.26	0.19	NIL
cfu/ml X 103	2.20	2.52	1.37	2.51	2.54	1.15	2.89	1.58	0.98	1.32	2.96	2.14
cfu/ml X 103	0.60	1.60	0.23	0.62	0.91	0.28	0.34	0.65	0.16	0.18	0.35	0.72

Appendix 4.6.11a:

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Checklist of phytoplankton in surface water of Enwhe Field in the wet season

Phytoplankton Taxa	SAMPLE POINTS																	CNT RL 1	CNT RL2	
	S W 1	SW 2	SW 3	S W 4	SW 5	SW 6	SW 7	S W 8	S W 9	SW 10	SW 11	SW 12	SW 13	SW 14	SW 15	SW 16	SW 17			
Bacillariophyta																				
Amphora ovails	28	14	19	19	18	8	6	4	2	2	5	10	4	8	8	3	4	4	4	18
Astenonella foremosc	56	16	12	22	12	6	5	6	14	0	12	9	14	15	3	4	4	6	4	4
Coscinodiscus radiata	14	26	31	9	25	12	2	10	16	1	9	21	12	17	52	12	2	14	12	12
Cyclotella bodanica	14	12	10	29	43	19	10	8	14	6	14	12	49	19	84	3	10	10	4	4
Cymbella ventricosa	45	15	10	10	54	0	14	6	0	9	6	8	42	37	32	6	36	12	10	10
Diatom cvulgare	12	19	24	34	69	2	16	8	0	10	8	8	2	45	15	17	47	4	12	12
Gamphonema germinatum	21	7	20	39	18	0	18	9	0	4	8	11	15	0	18	5	25	8	8	8
Gyrosigma sp.	9	12	34	8	26	0	2	14	12	2	19	12	20	0	38	12	29	14	12	12
Melosira granulate	24	12	16	51	15	12	14	9	14	3	2	9	6	28	0	19	10	12	14	14
Navicula radiosa	25	14	0	29	8	11	16	5	16	12	14	103	0	0	20	12	38	11	15	15
Nitschia palae	16	19	35	9	27	24	18	4	16	14	14	9	21	36	0	29	32	24	14	14
Suriella capronii	20	18	14	12	69	16	2	12	0	16	6	0	0	19	0	0	28	18	13	13
Synedra ulna	43	18	11	24	26	10	24	10	10	5	4	0	20	46	0	0	29	10	12	12
Tabell arie	14	14	17	46	19	16	10	14	0	8	9	73	51	7	79	0	51	16	4	4
Sub-Total	341	216	253	341	429	136	157	119	114	92	130	285	256	277	349	110	345	163	152	152
Cyanophyta																				
Anabaena circinalis	28	0	56	14	83	16	19	18	22	26	1	0	19	36	0	21	0	16	3	3

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Phytoplankton Taxa	SAMPLE POINTS																	CNT RL 1	CNT RL2
	S W 1	SW 2	SW 3	S W 4	SW 5	SW 6	SW 7	S W 8	S W 9	SW 10	SW 11	SW 12	SW 13	SW 14	SW 15	SW 16	SW 17		
Anabaena flos-aque	32	0	48	29	42	5	6	14	0	12	6	0	38	38	27	17	45	5	5
Anacystiscyanc e	0	0	65	19	0	2	10	16	1	9	1	15	41	0	0	0	49	2	1
Coelophaerium sp.	0	0	0	0	32	20	8	0	6	14	1	0	0	47	0	52	0	10	0
Cxoiphasphaeri alacustris	0	78	0	41	15	14	0	0	9	6	40	35	0	36	40	0	34	2	22
Merispomediael egans	17	17	22	54	5	16	8	0	10	1	2	42	61	0	0	20	0	9	6
Microcystisaeru ginosa	0	8	28	0	0	18	9	0	4	8	8	27	15	28	22	15	20	8	8
Nostoc	42	0	20	5	32	2	8	2	2	19	5	19	58	0	0	10	17	2	1
Oscillaturialacu stris	10	0	10	3	10	14	9	4	3	2	7	0	0	10	0	45	2	14	1
Phoridiumsp	18	34	24	18	31	16	5	2	12	14	9	0	43	46	39	17	17	9	14
Spirulinamassar tii	38	0	35	28	17	18	4	23	14	14	4	0	0	0	56	48	0	15	2
Sub-Total	185	137	308	211	267	141	86	79	83	125	84	138	275	241	184	245	184	92	63
Chlorophyta																			
Atlisdesmusfalcat us	15	15	20	18	9	41	9	48	12	8	7	9	4	28	89	73	41	22	2
Chlorella vulgaris	10	105	0	32	3	25	6	14	10	9	0	0	25	34	36	18	25	3	0
Closterium moniferum	56	3	0	2	45	13	1	12	7	6	0	73	0	0	8	22	13	6	6
Clostrerium aculare	7	45	17	0	0	0	4	9	6	6	3	0	12	39	0	0	0	7	3
Pediastrum boryanum	12	0	0	0	26	0	2	0	1	14	2	63	0	10	0	31	0	0	0

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Phytoplankton Taxa	SAMPLE POINTS																	CNT RL 1	CNT RL2
	S W 1	SW 2	SW 3	S W 4	SW 5	SW 6	SW 7	S W 8	S W 9	SW 10	SW 11	SW 12	SW 13	SW 14	SW 15	SW 16	SW 17		
<i>Pediastrum simplex</i>	0	0	0	57	4	64	6	2	8	11	0	0	12	0	8	18	64	1	6
<i>Protococcus</i> sp.	10	10	21	76	29	0	8	5	3	10	14	32	10	0	28	45	0	5	3
<i>Scenedesmus</i>	29	0	27	0	5	14	7	8	4	2	29	0	0	24	0	6	14	6	4
<i>Spirogyra communis</i>	28	65	0	18	3	29	9	0	0	6	16	24	2	10	18	42	29	2	9
<i>Staurastrum angulum</i>	3	0	0	57	0	0	8	0	2	9	14	5	21	2	0	16	0	4	12
<i>Staurastrum paradoxum</i>	28	11	0	0	39	0	8	14	0	1	19	0	0	0	5	0	0	2	4
<i>Volvox</i>	12	0	38	46	3	12	2	9	1	0	2	0	19	8	0	21	12	6	6
<i>Zygnema sterile</i>	50	0	0	0	0	0	0	2	2	4	1	0	0	36	94	0	0	2	9
Sub-Total	260	254	123	306	166	198	70	123	56	86	107	206	105	191	286	292	198	66	64
<i>Euglenophyta</i>																			
<i>Euglena acus</i>	10	8	0	0	0	0	0	1	3	16	11	10	16	0	15	0	39	23	17
<i>Euglena gracilis</i>	21	0	0	0	0	3	2	4	0	14	12	0	28	14	0	52	0	6	1
<i>Euglena viridis</i>	0	0	31	0	10	1	9	7	6	1	10	74	37	0	34	10	9	0	6
Sub-Total	31	8	31	0	10	4	11	12	9	31	33	84	81	14	49	62	48	29	24
<i>Dinophyta</i>																			
<i>Ceratium birundinella</i>	54	0	0	17	5	12	10	14	9	9	5	0	18	0	0	33	67	32	66
<i>Chorococcus</i>	9	91	67	8	22	14	16	12	18	8	6	0	79	24	0	0	47	21	9
<i>Peridinium</i>	33	6	62	38	7	2	4	4	7	9	6	19	0	25	21	39	0	14	1

Appendix 4.6.11b:

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Checklist of phytoplankton in surface water of Enwhe Field in the dry season

Phytoplankton taxa	SAMPLE POINTS																	CNTR L 1	CNT RL2
	SW 1	SW 2	SW 3	SW 4	SW 5	SW 6	SW 7	SW 8	SW 9	SW 10	SW 11	SW 12	SW 13	SW 14	SW 15	SW 16	SW 17		
Bacillariophyta																			
Amphora ovails	8	11	0	3	18	0	5	0	3	0	5	6	3	6	8	3	5	0	3
Astenonella foremosc	9	15	0	4	12	9	3	5	12	0	12	4	16	12	3	4	0	5	0
Coscinodiscus radiata	0	16	6	1	25	24	0	6	14	0	9	5	2	3	5	12	0	6	14
Cyclotella bodanica	12	12	5	3	12	4	9	4	7	1	14	4	8	15	5	3	9	4	0
Cymbella ventricosa	2	2	4	3	14	1	12	5	6	6	6	6	9	5	9	6	3	5	0
Diatom cvulgare	14	9	6	9	6	0	6	6	0	2	3	3	8	5	3	3	6	6	0
Gamphonema germinatum	9	6	9	11	14	0	8	9	0	4	9	10	3	4	0	5	1	9	6
Gyrosigma sp.	10	8	12	9	2	0	0	4	0	2	4	1	16	6	3	3	0	4	4
Melosira granulate	12	2	2	6	11	6	9	7	6	3	16	6	9	0	0	2	9	7	6
Navicula radiosa	5	9	0	25	9	14	14	11	2	12	10	12	14	0	9	12	14	11	7
Nitschia palae	11	10	0	6	17	2	9	3	9	14	9	3	12	0	0	3	2	3	2
Suriella capronii	25	9	18	12	6	9	3	66	1	16	5	0	6	6	0	0	3	10	4
Synedra ulna	42	7	9	6	5	11	13	9	3	5	2	1	13	0	0	0	69	9	9
Tabell arie	6	9	1	7	11	9	2	14	1	8	6	66	12	32	79	0	2	14	1
Sub-Total	165	125	72	105	162	89	93	149	64	73	110	127	131	94	124	44	123	93	56
Cyanophyta																			
Anabaena circinalis	5	9	8	8	19	31	9	5	2	13	0	1	0	6	0	3	1	3	9
Anabaena flos-aque	14	1	9	9	12	15	4	2	0	25	0	1	0	1	4	2	6	2	45
Anacystiscyance	1	0	8	21	0	6	2	4	2	6	2	6	0	0	0	0	4	5	12
Coelophaerium sp.	0	1	6	0	6	6	0	2	3	3	1	2	1	6	1	6	1	5	17

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Phytoplankton taxa	SAMPLE POINTS																	CNTR L 1	CNT RL2
	SW 1	SW 2	SW 3	SW 4	SW 5	SW 6	SW 7	SW 8	SW 9	SW 10	SW 11	SW 12	SW 13	SW 14	SW 15	SW 16	SW 17		
<i>Cxoiphasphaerial acustris</i>	0	11	14	0	8	9	0	4	9	10	2	9	1	8	9	1	9	4	2
<i>Merispome diaelegans</i>	4	5	2	0	0	4	0	2	4	13	2	4	6	8	0	9	1	6	6
<i>Microcystisaeruginosa</i>	1	5	11	6	9	7	6	3	16	6	19	9	0	1	5	9	5	2	9
<i>Nostoc</i>	8	12	9	14	14	11	2	12	10	12	12	7	4	2	1	5	9	5	1
<i>Oscillaturialacustris</i>	4	1	17	2	9	3	9	14	9	3	7	0	5	0	1	4	0	3	4
<i>Phoridium</i> sp.	23	14	6	0	3	66	1	16	5	0	2	1	4	0	9	8	6	5	9
<i>Spirulinamassartii</i>	42	1	8	8	6	1	2	2	2	9	1	0	1	1	4	5	1	5	3
Sub-Total	102	60	98	68	86	159	35	66	62	100	48	40	22	33	34	52	43	45	117
Chlorophyta																			
<i>Atlisdesmusfalcat</i> us	3	5	1	3	0	5	6	4	12	8	7	9	4	2	4	3	3	4	2
<i>Chlorella vulgaris</i>	9	3	5	0	4	12	1	1	12	1	0	1	25	7	2	2	1	3	0
<i>Closterium moniferum</i>	0	0	6	0	6	1	6	0	6	6	0	0	0	0	8	1	1	6	6
<i>Clostrerium aculare</i>	4	2	4	6	9	6	14	0	8	2	1	6	2	4	9	14	1	2	3
<i>Pediastrum boryanum</i>	1	12	5	8	12	9	2	0	0	9	1	8	9	6	10	6	0	6	0
<i>Pediastrum simplex</i>	0	6	6	0	2	9	11	6	9	4	6	8	6	9	12	14	0	8	20
<i>Protococcus</i> sp.	0	8	9	2	0	8	9	14	14	9	0	1	8	12	9	2	0	0	3
<i>Scenedesmus</i>	0	0	4	10	0	6	17	2	9	7	4	2	2	2	17	11	6	9	4
<i>Spirogyra communis</i>	6	9	7	9	11	12	6	9	3	0	5	0	9	0	25	9	14	14	2
<i>Staurastrum angulum</i>	14	14	11	0	9	13	0	11	13	9	5	5	10	0	6	17	2	9	12
<i>Staurastrum paradaxum</i>	2	9	3	0	14	9	3	14	0	1	5	0	0	36	12	6	9	3	4

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Phytoplankton taxa	SAMPLE POINTS																	CNTR L 1	CNT RL2
	SW 1	SW 2	SW 3	SW 4	SW 5	SW 6	SW 7	SW 8	SW 9	SW 10	SW 11	SW 12	SW 13	SW 14	SW 15	SW 16	SW 17		
Volvox	9	3	19	1	16	5	0	9	1	0	2	0	7	9	13	5	11	13	6
Zygnema sterile	11	13	9	0	5	2	1	2	2	4	1	0	0	1	8	0	0	2	9
Sub-Total	59	84	89	39	88	97	76	72	89	60	37	40	82	88	135	90	48	79	71
Euglenophyta																			
Euglena acus	10	3	4	0	9	9	5	0	8	16	2	10	6	0	15	0	39	23	17
Euglena gracilis	21	14	2	12	18	8	6	0	4	14	12	0	0	14	0	52	0	6	1
Euglena viridis	0	0	31	0	10	1	0	7	6	1	10	74	0	0	34	10	9	0	6
Sub-Total	31	17	37	12	37	18	11	7	18	31	24	84	6	14	49	62	48	29	24
Dinophyta																			
Ceratium birundinella	54	0	0	1	5	12	6	4	9	9	0	1	2	0	9	3	9	3	4
Chorococcus	9	1	3	8	22	14	1	12	4	8	1	0	2	0	7	9	11	13	6
Peridinium	33	6	62	38	7	2	0	4	7	9	2	4	1	0	0	36	0	2	9

Appendix 4.6.11c:

Checklist of Zooplankton in surface water of Enwhe Field in the wet season

Environmental Impact Assessment of Enwhe Field Development Project – Final Report

Zooplankton taxa	SAMPLE POINTS																	
	SW 1	SW 2	SW 3	SW 4	SW 5	SW 6	SW 7	SW 8	SW 9	SW 10	SW1 1	SW1 2	SW1 3	SW1 4	SW1 5	SW1 6	SW1 7	
Protozoa																		
Coleps sp.	14	8	0	15	15	0	10	37	9	9	25	14	10	16	16	25	0	
Loxodessp	0	10	15	2	2	28	15	0	4	0	17	0	4	0	7	4	28	
Sarcodinasp	8	15	31	1	11	0	2	7	0	10	0	13	32	0	3	0	0	
Urocentrum sp.	0	6	3	10	0	0	14	2	4	1	13	2	6	10	6	0	0	
Vorticella sp.	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Sub-Total	25	39	49	28	28	28	41	46	17	20	55	29	52	26	32	29	28	
Rotifera																		
Brachionussp	10	2	0	10	7	5	3	0	5	0	0	14	6	9	6	14	0	
Stentor sp.	2	0	5	8	0	14	27	11	0	7	4	19	8	12	9	2	0	
Asphlanchiabrightwe lli	0	7	11	2	0	15	0	0	0	8	1	26	0	2	9	11	6	
Philodina sp.	1	5	10	20	29	10	3	4	0	9	0	26	2	16	8	9	14	
Rotaria sp.	0	0	15	0	19	0	14	35	4	10	16	4	10	16	6	17	2	
Monostylasp	36	5	0	9	0	7	2	12	19	12	2	7	9	11	12	6	9	
Polyarthra	0	8	1	6	4	7	1	3	3	6	13	11	0	9	13	0	11	
Kerratela	4	0	2	18	7	7	27	0	10	4	0	3	0	14	9	3	14	
Chilodonella	0	0	45	11	11	7	2	0	17	5	11	19	1	16	5	10	9	
Filiniasp	0	21	6	0	0	0	35	7	15	21	16	13	16	18	16	12	10	
Sub-Total	53	48	95	84	77	72	114	72	73	82	63	142	52	123	93	84	75	
Copepoda																		
Cyclops sp.	15	18	5	34	10	58	43	25	5	10	22	29	60	58	19	23	3	
Limnocalanusmacrur us	2	8	2	0	4	0	7	4	4	8	12	3	4	3	7	4	2	
Macrocylopsater	0	2	10	13	32	0	3	0	8	12	6	13	32	0	3	0	12	
Naplius I of copepoda	37	0	1	2	6	10	6	0	0	0	8	2	6	10	6	0	16	
Senecellacalanoidea	0	1	2	0	0	0	0	0	0	1	0	0	0	0	0	0	19	
Moina	4	6	0	1	7	4	3	6	53	4	2	1	7	4	3	6	16	

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Zooplankton taxa	SAMPLE POINTS																
	SW 1	SW 2	SW 3	SW 4	SW 5	SW 6	SW 7	SW 8	SW 9	SW 10	SW1 1	SW1 2	SW1 3	SW1 4	SW1 5	SW1 6	SW1 7
Thermocyclopsneglectus	15	3	3	0	3	0	14	1	0	22	29	1	3	1	14	1	19
Tropodiatomussp	4	0	5	0	1	9	15	9	0	12	3	12	14	19	14	16	18
Mesocyclops	14	0	15	4	15	15	0	7	0	22	16	10	9	9	11	14	12
Sub-Total	91	38	43	54	78	96	91	52	70	91	98	71	135	104	77	64	117
Cladocera																	
Daphnia pulex	7	12	8	26	5	9	21	0	2	5	22	12	14	0	0	12	9
Daphnia barbata	0	4	5	10	0	18	0	7	28	0	13	2	2	1	0	1	1
Sub-Total	7	16	13	36	5	27	21	7	30	5	35	14	16	1	0	13	10
Insecta																	
Chaoborus sp.	0	0	21	34	6	6	1	1	2	11	0	36	12	16	16	12	12
Cypris sp.	1	6	32	0	18	0	8	0	10	0	15	0	3	4	8	1	2

Appendix 4.6.11d:

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Checklist of Zooplankton in surface water of Enwhe Field in the dry season

Zooplankton taxa	SAMPLE POINTS																	
	SW 1	SW 2	SW 3	SW 4	SW 5	SW 6	SW 7	SW 8	SW 9	SW 10	SW1 1	SW1 2	SW1 3	SW1 4	SW1 5	SW1 6	SW1 7	
Protozoa																		
Coleps sp.	0	8	0	5	6	0	2	6	6	9	5	0	6	6	3	2	0	
Loxodessp	0	1	1	2	2	2	1	0	4	0	1	0	4	2	2	4	6	
Sarcodinasp	0	2	9	1	4	0	7	2	0	5	0	3	6	2	3	1	1	
Urocentrum sp.	0	1	3	4	0	0	2	2	4	1	3	2	6	1	3	1	1	
Vorticella sp.	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	
Sub-Total	1	12	13	12	12	3	12	10	14	15	9	5	22	11	11	8	8	
Rotifera																		
Brachionussp	2	2	0	1	1	4	3	1	5	0	2	2	2	3	6	14	0	
Stentor sp.	2	1	4	6	0	6	5	2	2	2	4	7	1	1	9	2	0	
Asphlanchiabrightwelli	1	4	6	1	0	3	1	0	2	8	1	3	3	1	1	4	5	
Philodina sp.	3	6	5	8	6	1	1	4	3	2	1	2	2	1	8	9	2	
Rotaria sp.	9	0	6	0	2	0	4	4	4	2	7	4	1	3	1	4	2	
Monostylasp	9	3	0	6	0	1	2	6	4	4	2	0	1	1	12	1	9	
Polyarthra	5	5	1	2	4	7	1	3	3	3	3	2	5	1	1	0	2	
Kerratela	1	0	2	7	2	0	6	0	4	1	0	3	1	2	9	3	14	
Chilodonella	0	0	9	9	4	7	2	0	4	5	2	3	1	2	5	2	2	
Filiniasp	0	9	4	1	0	0	3	7	3	2	2	4	16	2	7	3	6	
Sub-Total	32	30	37	41	19	29	28	27	34	29	24	30	33	17	59	42	42	
Copepoda																		
Cyclops sp.	0	1	5	6	4	5	6	7	3	2	3	4	3	6	2	2	3	
Limnocalanusmacrurus	2	2	2	0	4	0	6	4	2	8	3	3	4	3	7	3	2	
Macrocyclopsater	0	2	1	1	2	0	3	5	8	2	6	3	3	1	3	1	2	
Naplius I of copepoda	2	0	1	2	6	4	2	7	0	0	8	2	6	3	1	1	1	
Senecellacalanoidea	0	1	2	0	0	0	0	3	0	2	3	2	4	0	0	0	1	

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Zooplankton taxa	SAMPLE POINTS																
	SW 1	SW 2	SW 3	SW 4	SW 5	SW 6	SW 7	SW 8	SW 9	SW 10	SW1 1	SW1 2	SW1 3	SW1 4	SW1 5	SW1 6	SW1 7
Moina	4	4	0	1	7	4	3	6	2	4	2	2	7	4	3	6	1
Thermocyclopsneglectus	1	0	3	0	3	0	4	1	2	2	3	0	3	1	1	1	1
Tropodiatomussp	4	0	5	0	1	9	6	6	0	2	3	0	3	12	3	1	3
Mesocyclops	1	0	15	4	6	4	0	7	2	3	3	4	1	9	2	3	3
Sub-Total	14	10	34	14	33	26	30	46	19	25	34	20	34	39	22	18	17
Cladocera																	
Daphnia pulex	1	1	3	2	5	2	6	1	2	1	3	3	2	2	1	6	0
Daphnia barbata	0	1	1	3	1	2	0	1	3	1	6	2	1	2	0	1	1
Sub-Total	1	2	4	5	6	4	6	2	5	2	9	5	3	4	1	7	1
Insecta																	
Chaoborus sp.	1	1	0	1	6	0	1	1	2	2	0	14	12	6	1	0	3
Cypris sp.	0	6	0	0	2	1	8	0	0	0	0	0	1	4	3	1	2

Appendix 4.6.11e:

Checklist of Benthic macro fauna in surface water of Enwhe Field in the wet season

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Benthic macro fauna	SW 1	SW 2	SW 3	SW 4	SW 5	SW 6	SW 7	SW 8	SW 9	SW 10	SW 11	SW 12	SW 13	SW 14	SW 15	SW 16	SW 17	CNTR L 1	CNT RL2
Annelida																			
Neriessp.	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	1	1	2
Brachiura	1	1	1	2	0	6	1	0	0	1	1	1	1	0	1	0	2	1	1
Chaetogaster	2	0	1	1	0	0	0	2	1	0	0	0	1	1	0	2	1	2	1
Stylaria	0	0	0	0	1	0	0	0	0	1	0	1	0	1	0	0	1	2	2
Nais	0	1	1	0	0	0	1	0	0	1	0	1	1	1	1	1	0	1	1
Sub-Total	3	2	3	3	2	6	2	3	1	3	1	3	3	3	2	3	5	7	7
Arthropoda																			
1. Crustaceans																			
Cardisomasp.	2	2	2	6	4	5	4	0	5	6	9	4	2	8	9	6	6	0	2
2. Insecta																			
Diptera																			
Chironomus(larva/pupa)	0	1	1	0	0	0	0	0	1	0	0	1	1	1	1	0	0	0	2
Pentanuera	1	0	0	1	0	1	0	0	1	0	1	0	1	0	1	0	0	1	1
Anopheles larvae	0	1	0	1	1	0	2	0	0	0	0	0	1	1	0	2	0	0	1
Smilium larvae	1	0	0	0	1	0	0	1	1	1	1	0	1	1	0	1	1	3	1
Sub-Total	2	2	1	2	2	1	2	1	3	1	2	1	4	3	2	3	1	4	5
Plecoptera																			
Ephemera	0	0	1	0	1	0	0	0	0	1	1	1	1	1	1	1	1	2	0
Gyrinuspp.	0	0	1	0	0	1	1	1	1	0	0	0	0	1	1	0	0	1	1
Odonata nymphs	1	1	0	1	1	0	2	0	2	1	2	1	1	1	2	1	1	1	1
Water boatman	0	0	0	0	0	1	0	1	0	0	1	0	0	1	0	0	0	0	0
Sub-Total	1	1	2	1	2	2	3	2	3	2	4	2	2	4	4	2	2	4	2
Coleoptera																			
Dytiscus	1	0	1	0	0	0	1	0	2	0	2	1	1	1	1	1	1	1	1

Appendix 4.6.11f:

Checklist of Benthic macro fauna in surface water of Enwhe Field in the dry season

Benthic macro fauna	S W 1	SW 2	SW 3	S W 4	SW 5	SW 6	SW 7	S W 8	S W 9	SW 10	SW 11	SW 12	SW 13	SW 14	SW 15	SW 16	SW 17	CNT RL 1	CNT RL2
Annelida																			
Neriessp.	0	1	0	0	0	0	0	1	0	0	0	0	1	1	0	0	0	0	0
Brachiura	1	0	1	0	1	0	0	1	0	1	1	0	1	0	1	0	1	0	0
Chaetogaster	0	0	0	1	0	1	1	0	0	0	0	0	0	0	0	1	0	1	0
Stylaria	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Nais	0	1	0	0	0	1	0	1	0	0	1	1	0	0	0	1	0	1	0
Sub-Total	1	2	1	1	1	2	1	3	0	1	2	1	2	1	1	2	1	2	1
Arthropoda																			
1. Crustaceans																			
Cardisomasp.	1	1	0	1	1	0	1	0	1	1	1	0	0	1	1	0	1	0	1
2. Insecta																			
Diptera																			
Chironomus(larva/pupa)	1	1	0	0	1	1	0	0	1	1	0	1	1	1	1	0	0	0	1
Pentanaera	0	1	1	0	0	1	1	0	0	1	1	0	1	0	1	0	0	0	1
Anopheles larvae	0	0	0	1	0	0	1	0	0	0	0	0	0	1	0	1	0	0	0
Smilium larvae	0	0	1	1	0	0	0	1	1	1	0	0	0	1	0	0	1	0	0
Sub-Total	1	2	2	2	1	2	2	1	2	3	1	1	2	3	2	1	1	0	2
Plecoptera																			
Ephemera	0	0	1	0	1	0	0	0	0	0	0	0	0	1	0	0	1	1	0
Gyrinussp.	0	0	0	0	0	1	1	1	1	0	0	0	0	0	1	0	0	1	0
Odonata nymphs	1	1	0	1	1	0	1	0	1	0	1	0	0	0	0	0	0	0	1
Water boatman	0	0	0	0	0	0	0	1	0	0	1	0	0	1	0	0	0	0	0

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Benthic macro fauna	S W 1	SW 2	SW 3	S W 4	SW 5	SW 6	SW 7	S W 8	S W 9	SW 10	SW 11	SW 12	SW 13	SW 14	SW 15	SW 16	SW 17	CNT RL 1	CNT RL2
Sub-Total	1	1	1	1	2	1	2	2	2	0	2	0	0	2	1	0	1	2	1
Coleoptera																			
Dytiscus	1	0	1	0	0	0	1	0	1	0	0	1	1	1	0	1	0	0	1

Appendix 4.6.5.1 a:

Physicochemical measurement in soils of the study area during wet season

S/N	FIELD CODE	pH	ELECTRICAL CONDUCTIVITY (uS/cm)	TOC (O/O)	O & G (ppm)	NH4+ (mg/kg)	NO3- (mg/kg)	SO42- (mg/kg)	TOTAL PHOSPHOROUS (mg/kg)	TOTAL NITROGEN (O/O)	BULK DENSITY (g/cm)
1	SS1 (0-15)	6.40	37.40	0.10	3.4	0.139	4.257	2.39	0.99	0.0014	0.27
2	SS1 (15-30)	5.90	41.30	0.20	2.8	0.190	5.864	1.53	1.39	0.0011	0.24
3	SS2 (0-15)	6.80	45.40	0.18	1.9	0.165	0.956	2.39	1.86	0.0018	0.26
4	SS2 (15-30)	7.01	40.30	0.21	2.4	0.162	2.641	1.03	0.91	0.0011	0.25
5	SS3 (0-15)	6.88	56.30	0.26	3.5	0.113	2.564	1.37	2.02	0.0014	0.22
6	SS3 (15-30)	6.56	48.90	0.21	2.1	0.128	1.724	3.62	1.70	0.0011	0.26
7	SS4 (0-15)	5.41	70.10	0.08	1.6	0.193	2.151	1.73	1.21	0.0019	0.20
8	SS4 (15-30)	5.47	87.00	0.04	2.1	0.184	1.582	2.42	1.08	0.0012	0.50
9	SS5 (0-15)	5.90	106.66	0.04	3.7	0.184	0.675	4.60	3.93	0.0011	0.17
10	SS5 (15-30)	6.04	152.00	0.03	2.2	0.080	1.531	0.99	0.63	0.0013	0.17
11	SS6 (0-15)	6.78	16.40	0.22	3.3	0.162	2.298	2.73	2.29	0.0019	0.20
12	SS6 (15-30)	7.19	18.82	0.10	3.5	0.162	0.939	1.54	2.60	0.0012	0.17
13	SS7 (0-15)	5.03	72.40	0.16	2.7	0.149	2.786	1.45	2.32	0.0019	0.20
14	SS7 (15-30)	4.23	89.90	0.06	2.5	0.134	1.120	2.36	2.11	0.0013	0.22
15	SS8 (0-15)	7.29	46.90	0.16	2.2	0.130	0.911	2.36	2.12	0.0011	0.10
16	SS8 (15-30)	7.17	196.30	0.09	2.1	0.130	0.212	1.90	2.08	0.0011	0.17
17	SS9 (0-15)	7.29	188.60	0.16	4.3	0.264	0.314	4.10	2.65	0.0012	0.20
18	SS9 (15-30)	7.06	154.80	0.15	0.6	0.140	5.837	4.19	0.80	0.0016	0.18
19	SS10 (0-15)	7.52	108.20	0.03	2.6	0.285	0.720	3.64	1.15	0.0011	0.17
20	SS10 (15-30)	7.02	40.20	0.12	2.1	0.147	1.576	5.65	1.14	0.0012	0.25
21	SS11 (0-15)	6.89	62.10	0.19	1.1	0.158	4.239	6.57	1.21	0.0012	0.21
22	SS11 (15-30)	6.44	103.50	0.17	2.5	0.136	2.508	3.37	1.21	0.0010	0.22
23	SS12 (0-15)	5.02	121.00	0.15	3.3	0.251	1.244	4.56	1.30	0.0011	0.25
24	SS12 (15-30)	5.38	36.40	0.12	1.6	0.219	2.141	5.56	1.16	0.0017	0.25
25	SS13 (0-15)	5.91	47.00	0.03	2.8	0.114	0.742	4.65	1.68	0.0011	0.19
26	SS13 (15-30)	5.30	39.10	0.06	4.4	0.155	0.528	4.74	1.59	0.0013	0.15

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S/N	FIELD CODE	pH	ELECTRICAL CONDUCTIVITY (uS/cm)	TOC (O/O)	O & G (ppm)	NH4+ (mg/kg)	NO3- (mg/kg)	SO42- (mg/kg)	TOTAL PHOSPHOROUS (mg/kg)	TOTAL NITROGEN (O/O)	BULK DENSITY (g/cm)
27	SS14 (0-15)	6.61	58.30	0.18	1.2	0.240	1.988	3.00	3.42	0.0022	0.50
28	SS14 (15-30)	6.32	43.60	0.15	2.4	0.169	2.618	4.10	4.52	0.0018	0.19
29	SS15 (0-15)	5.00	80.70	0.23	2.6	0.154	4.371	2.18	3.16	0.0012	0.25
30	SS15 (15-30)	4.70	17.05	0.08	1.6	0.106	3.672	6.11	1.93	0.0011	0.23
31	SS16 (0-15)	7.09	41.60	0.16	0.9	0.145	6.532	5.20	1.72	0.0014	0.22
32	SS16 (15-30)	6.12	52.26	0.05	1.5	0.198	0.184	2.09	1.08	0.0013	0.17
33	SS17 (0-15)	5.83	41.70	0.13	3.7	0.115	0.548	2.64	2.11	0.0013	0.24
34	SS17 (15-30)	5.25	56.30	0.16	1.3	0.208	1.341	1.45	1.06	0.0017	0.15
35	SS18 (0-15)	5.71	85.90	0.12	3.6	0.137	1.080	1.77	1.16	0.0016	0.10
36	SS18 (15-30)	5.93	90.31	0.11	1.1	0.114	0.562	2.45	1.20	0.0011	0.17
37	SS19 (0-15)	5.43	47.00	0.13	0.7	0.148	3.221	2.39	3.02	0.0013	0.25
38	SS19 (15-30)	4.75	26.90	0.07	1.9	0.158	5.468	1.53	4.39	0.0015	0.25
39	SS20 (0-15)	5.84	41.20	0.17	2.8	0.154	1.323	2.39	3.86	0.0026	0.17
40	SS20 (15-30)	5.46	28.20	0.06	1.3	0.204	1.336	1.03	3.91	0.0013	0.23
41	SS21 (0-15)	6.04	72.60	0.12	4.7	0.105	3.111	1.37	2.02	0.0016	0.21
42	SS21 (15-30)	5.99	58.40	0.19	2.3	0.282	0.812	3.62	1.70	0.0016	0.24
43	SS22 (0-15)	6.71	108.40	0.11	1.2	0.106	2.599	1.73	1.21	0.0011	0.27
44	SS22 (15-30)	6.60	128.80	0.05	1.8	0.105	0.190	2.42	1.08	0.0016	0.20
45	SS23 (0-15)	5.34	31.60	0.16	1.7	0.108	0.831	4.60	4.93	0.0013	0.24
46	SS23 (15-30)	5.55	47.70	0.09	4.6	0.117	0.398	0.99	5.63	0.0018	0.21
47	SS24 (0-15)	4.89	48.50	0.14	1.6	0.185	2.581	2.73	2.29	0.0012	0.25
48	SS24 (15-30)	4.28	33.80	0.01	4.5	0.163	2.634	1.54	2.60	0.0015	0.20
49	SS25 (0-15)	5.71	48.30	0.22	2.7	0.144	0.111	1.45	2.32	0.0013	0.17
50	SS25 (15-30)	5.11	26.30	0.06	4.2	0.132	7.442	2.36	2.11	0.0011	0.20
51	SS26 (0-15)	6.38	49.80	0.13	1.4	0.119	4.910	2.36	2.12	0.0014	0.25
52	SS26 (15-30)	6.09	76.80	0.15	2.8	0.109	2.859	1.90	1.12	0.0014	0.19
53	SS27 (0-15)	4.69	20.03	0.12	4.2	0.156	0.365	4.10	3.13	0.0014	0.17

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S/N	FIELD CODE	pH	ELECTRICAL CONDUCTIVITY (uS/cm)	TOC (O/O)	O & G (ppm)	NH4+ (mg/kg)	NO3- (mg/kg)	SO42- (mg/kg)	TOTAL PHOSPHOROUS (mg/kg)	TOTAL NITROGEN (O/O)	BULK DENSITY (g/cm)
54	SS27 (15-30)	4.72	36.07	0.11	3.1	0.113	0.111	4.19	3.81	0.0014	0.15
55	SS28 (0-15)	4.79	76.40	0.13	3.6	0.142	3.470	3.64	1.15	0.0023	0.21
56	SS28 (15-30)	4.61	100.30	0.01	3.3	0.112	0.434	5.65	1.19	0.0020	0.17
57	SS29 (0-15)	4.33	68.50	0.15	1.8	0.196	2.824	6.57	1.22	0.0014	0.20
58	SS29 (15-30)	4.83	114.50	0.15	2.5	0.166	3.191	3.37	1.14	0.0012	0.18
59	SS30 (0-15)	5.05	58.60	0.12	0.6	0.132	0.990	4.56	1.58	0.0012	0.19
60	SS30 (15-30)	4.37	47.40	0.13	2.7	0.142	0.331	5.56	1.48	0.0013	0.17
61	SS31 (0-15)	4.32	87.00	0.08	3.7	0.311	0.742	4.65	1.40	0.0014	0.17
62	SS31 (15-30)	4.31	51.00	0.12	1.4	0.241	2.795	4.74	2.64	0.0015	0.23
63	SS32 (0-15)	3.86	20.39	0.16	1.8	0.230	1.683	3.00	0.72	0.0011	0.20
64	SS32 (15-30)	5.29	82.70	0.14	2.2	0.108	2.146	4.10	1.32	0.0011	0.20
65	SS33 (0-15)	3.67	81.60	0.17	3.4	0.112	7.920	2.18	4.04	0.0011	0.24
66	SS33 (15-30)	4.02	61.40	0.11	0.9	0.109	4.775	6.11	5.10	0.0011	0.20
67	SS34 (0-15)	4.34	48.10	0.12	2.9	0.127	8.025	5.20	1.06	0.0010	0.25
68	SS34 (15-30)	4.43	18.40	0.09	3.5	0.105	3.587	2.09	1.05	0.0011	0.20
69	SS35 (0-15)	4.72	72.50	0.13	1.2	0.271	4.344	2.64	1.05	0.0011	0.18
70	SS35 (15-30)	4.81	64.30	0.11	2.6	0.157	3.176	1.45	1.07	0.0010	0.19
71	SS36 (0-15)	3.94	59.30	0.09	1.4	0.212	7.598	1.77	3.06	0.0011	0.25
72	SS36 (15-30)	4.47	63.90	0.10	2.8	0.145	3.348	2.45	3.24	0.0011	0.17
73	SS37 (0-15)	4.82	37.70	0.06	2.1	0.102	6.418	2.39	1.12	0.0011	0.33
74	SS37 (15-30)	4.18	37.70	0.10	4.5	0.146	4.064	1.53	1.04	0.0010	0.25
75	SS38 (0-15)	5.82	158.60	0.16	1.2	0.112	8.065	2.39	1.03	0.0010	0.26
76	SS38 (15-30)	5.72	81.10	0.08	4.2	0.156	7.357	1.03	1.23	0.0011	0.25
77	SS39 (0-15)	4.31	29.30	0.10	0.9	0.273	8.965	1.37	1.21	0.0010	0.20
78	SS39 (15-30)	4.38	23.90	0.08	1.7	0.212	7.605	3.62	1.20	0.0011	0.21
79	SS40 (0-15)	4.55	34.60	0.29	0.8	0.194	8.337	1.73	2.16	0.0010	0.25
80	SS40 (15-30)	4.24	23.20	0.03	1.5	0.262	9.491	2.42	3.73	0.0010	0.20

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S/N	FIELD CODE	pH	ELECTRICAL CONDUCTIVITY (uS/cm)	TOC (O/O)	O & G (ppm)	NH4+ (mg/kg)	NO3- (mg/kg)	SO42- (mg/kg)	TOTAL PHOSPHOROUS (mg/kg)	TOTAL NITROGEN (O/O)	BULK DENSITY (g/cm)
81	SS41 (0-15)	4.82	137.70	0.03	2.3	0.113	7.044	4.60	1.36	0.0010	0.33
82	SS41 (15-30)	4.24	40.80	0.09	3.8	0.126	7.581	0.99	1.17	0.0010	0.25
83	SS42 (0-15)	3.90	80.00	0.06	2.4	0.255	8.932	3.51	0.73	0.0010	0.26
84	SS42 (15-30)	4.10	26.60	0.09	3.0	0.193	6.044	1.54	1.34	0.0010	0.21
85	SS43 (0-15)	4.52	36.60	0.06	1.6	0.128	8.582	1.45	1.16	0.0011	0.25
86	SS43 (15-30)	4.58	21.10	0.10	0.6	0.171	6.875	1.18	4.08	0.0011	0.22
87	SS44 (0-15)	4.91	48.60	0.13	3.8	0.186	6.771	1.71	4.08	0.0011	0.22
88	SS44 (15-30)	4.81	51.30	0.17	4.1	0.128	7.035	1.47	1.05	0.0010	0.20
89	SS45 (0-15)	4.30	99.90	0.14	2.5	0.164	0.472	1.20	1.10	0.0010	0.20
90	SS45 (15-30)	4.09	80.10	0.06	0.7	0.214	0.401	4.19	1.70	0.0010	0.20
91	SS46 (0-15)	4.48	96.80	0.03	2.6	0.206	9.862	3.64	1.27	0.0010	0.25
92	SS46 (15-30)	4.89	58.40	0.21	1.6	0.147	5.239	3.98	2.36	0.0010	0.25
93	SS47 (0-15)	4.27	35.00	0.14	2.1	0.202	6.265	1.05	1.12	0.0010	0.25
94	SS47 (15-30)	4.96	52.80	0.15	2.5	0.136	5.208	3.37	1.12	0.0010	0.26
95	SS48 (0-15)	4.61	83.20	0.13	2.5	0.175	1.097	3.82	2.43	0.0010	0.20
96	SS48 (15-30)	5.03	26.10	0.13	3.2	0.219	0.320	3.29	1.14	0.0010	0.20
97	SS49 (0-15)	5.01	37.70	0.08	1.3	0.214	3.301	2.43	1.15	0.0011	0.25
98	SS49 (15-30)	5.97	161.90	0.14	0.9	0.193	1.244	4.74	1.57	0.0020	0.17
99	SS50 (0-15)	4.14	60.30	0.14	4.3	0.138	3.526	3.00	1.07	0.0019	0.20
100	SS50 (15-30)	5.73	80.30	0.13	2.7	0.156	7.777	4.10	1.17	0.0018	0.25
101	SS51 (0-15)	5.42	56.00	0.15	2.6	0.114	4.870	2.18	1.07	0.0022	0.25
102	SS51 (15-30)	5.00	18.12	0.08	2.9	0.203	7.972	4.75	0.93	0.0019	0.28
103	SS52 (0-15)	5.13	62.40	0.11	0.9	0.212	7.560	4.73	1.12	0.0021	0.28
104	SS52 (15-30)	5.24	53.20	0.15	1.5	0.198	4.026	2.09	1.32	0.0020	0.31
105	SS53 (0-15)	5.10	33.30	0.02	2.5	0.128	9.313	2.64	3.21	0.0020	0.22
106	SS53 (15-30)	4.54	31.10	0.10	0.8	0.120	8.170	1.45	3.20	0.0022	0.24
107	SS54 (0-15)	5.06	113.50	0.14	3.6	0.116	0.367	1.77	1.23	0.0019	0.32

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S/N	FIELD CODE	pH	ELECTRICAL CONDUCTIVITY (uS/cm)	TOC (O/O)	O & G (ppm)	NH4+ (mg/kg)	NO3- (mg/kg)	SO42- (mg/kg)	TOTAL PHOSPHOROUS (mg/kg)	TOTAL NITROGEN (O/O)	BULK DENSITY (g/cm)
108	SS54 (15-30)	5.34	86.80	0.15	4.2	0.391	1.180	2.45	1.11	0.0020	0.28
109	SS55 (0-15)	5.24	52.60	0.12	6.3	0.119	0.870	2.39	1.35	0.0021	0.21
110	SS55 (15-30)	5.78	42.10	0.19	5.9	0.024	0.959	1.53	1.79	0.0020	0.22
111	SS56 (0-15)	4.88	52.70	0.17	4.1	0.116	9.554	2.39	1.71	0.0022	0.26
112	SS56 (15-30)	4.38	34.34	0.13	4.9	0.115	9.483	1.03	1.12	0.0012	0.27
113	SS57 (0-15)	4.03	56.80	0.19	0.9	0.116	8.837	1.37	1.62	0.0011	0.28
114	SS57 (15-30)	4.22	21.30	0.05	6.2	0.108	9.988	3.01	1.39	0.0011	0.20
115	SS58 (0-15)	3.94	73.40	0.12	1.3	0.105	8.574	1.73	2.08	0.0011	0.29
116	SS58 (15-30)	4.28	47.40	0.08	1.5	0.353	9.565	2.42	0.72	0.0015	0.25
117	SS59 (0-15)	4.96	52.00	0.17	1.2	0.107	7.202	4.60	1.09	0.0013	0.25
118	SS59 (15-30)	4.82	27.00	0.16	2.8	0.021	9.972	1.43	1.32	0.0011	0.25
119	SS60 (0-15)	4.24	53.60	0.12	1.4	0.105	8.434	1.44	3.15	0.0014	0.29
120	SS60 (15-30)	4.75	74.70	0.16	3.3	0.104	6.684	1.54	4.16	0.0014	0.22
121	SS61 (0-15)	4.69	29.90	0.14	3.9	0.105	8.542	1.68	1.13	0.0038	0.28
122	SS61 (15-30)	4.92	15.20	0.18	3.4	0.117	6.768	2.18	1.15	0.0042	0.24
123	SS62 (0-15)	5.23	50.60	0.11	3.6	0.113	1.717	3.13	1.11	0.0049	0.17
124	SS62 (15-30)	4.23	44.20	0.14	4.6	0.381	2.576	1.90	0.51	0.0010	0.22
125	SS63 (0-15)	5.28	19.50	0.13	1.4	0.116	0.612	1.20	1.30	0.0027	0.27
126	SS63 (15-30)	5.19	11.62	0.20	4.2	0.023	0.432	2.06	1.10	0.0015	0.15
127	SSC1 (0-15)	4.59	175.50	0.09	1.9	0.114	9.553	3.64	1.15	0.0012	0.20
128	SSC1 (15-30)	5.06	153.70	0.13	3.2	0.113	9.315	3.19	1.39	0.0011	0.15
129	SSC2 (0-15)	6.18	36.40	0.25	3.9	0.113	0.352	1.04	1.36	0.0018	0.20
130	SSC2 (15-30)	6.67	13.49	0.29	2.3	0.218	0.438	3.37	1.24	0.0013	0.18

Appendix 4.6.5.1 a Contd.:

Physicochemical measurement in soils of the study area during wet season

S/N	FIELD CODE	THC (mg/kg)	Phenol (mg/kg)	Porosity (% pore space)	Permeability (K-4 cm/hr)	Cl- (mg/kg)	% Sand	% Silt	% Clay	Texture
1	SS1 (0-15)	1.8	<0.05	57.69	1.2	8.71	75.00	10.10	14.90	LOAMY SAND
2	SS1 (15-30)	0.7	<0.05	43.56	1.2	10.04	87.00	1.00	12.00	LOAM SAND
3	SS2 (0-15)	0.9	<0.05	51.63	1.2	13.26	88.00	1.00	11.00	LOAM SAND
4	SS2 (15-30)	0.9	<0.05	42.86	0.8	13.40	86.00	3.00	11.00	LOAM SAND
5	SS3 (0-15)	1.4	<0.05	50.96	1.2	15.86	78.00	7.00	15.00	SANDY LOAM
6	SS3 (15-30)	0.7	<0.05	43.51	0.8	12.91	78.00	7.00	15.00	SANDY LOAM
7	SS4 (0-15)	0.5	<0.05	33.33	1.1	13.24	68.00	9.00	23.00	SANDY CLAY LOAM
8	SS4 (15-30)	0.7	<0.05	66.67	1.0	20.89	84.00	4.00	12.00	LOAM SAND
9	SS5 (0-15)	1.1	<0.05	47.70	1.5	43.59	97.20	0.30	2.50	SAND
10	SS5 (15-30)	0.5	<0.05	60.05	1.0	47.45	75.00	12.00	13.00	SANDY LOAM
11	SS6 (0-15)	1.2	<0.05	45.21	1.7	5.30	86.00	2.00	12.00	LOAM SAND
12	SS6 (15-30)	1.4	<0.05	33.94	0.8	5.09	47.50	27.20	25.30	SANDY LOAM
13	SS7 (0-15)	1.1	<0.05	36.17	1.0	18.65	87.00	4.00	9.00	LOAM SAND
14	SS7 (15-30)	0.9	<0.05	40.25	0.8	30.44	85.00	1.00	14.00	LOAM SAND
15	SS8 (0-15)	0.8	<0.05	40.13	1.2	16.04	69.50	1.00	17.50	SANDY LOAM

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S/N	FIELD CODE	THC (mg/kg)	Phenol (mg/kg)	Porosity (% pore space)	Permeability (K-4 cm/hr)	Cl- (mg/kg)	% Sand	% Silt	% Clay	Texture
16	SS8 (15-30)	0.5	<0.05	49.25	1.2	46.50	85.00	6.80	8.20	SAND
17	SS9 (0-15)	1.8	<0.05	48.98	1.2	52.32	12.00	38.20	49.80	SILT LOAM
18	SS9 (15-30)	<0.1	<0.05	47.14	1.8	43.40	71.00	2.00	27.00	SANDY CLAY LOAM
19	SS10 (0-15)	0.7	<0.05	47.70	1.2	37.78	92.10	6.20	1.70	SAND
20	SS10 (15-30)	0.9	<0.05	52.20	1.3	15.14	87.00	1.00	12.00	LOAM SAND
21	SS11 (0-15)	<0.1	<0.05	51.93	1.1	16.88	88.00	1.00	11.00	LOAM SAND
22	SS11 (15-30)	<0.1	<0.05	38.05	1.4	33.59	88.60	4.10	7.30	SAND
23	SS12 (0-15)	1.2	<0.05	50.45	1.2	42.84	85.90	5.90	8.20	SAND
24	SS12 (15-30)	0.4	<0.05	33.33	1.4	12.09	87.20	5.20	7.60	SAND
25	SS13 (0-15)	0.6	<0.05	43.68	0.7	17.59	89.10	2.80	8.10	SAND
26	SS13 (15-30)	1.0	<0.05	47.14	0.8	8.33	78.40	5.80	15.80	LOAMY SAND
27	SS14 (0-15)	<0.1	<0.05	60.19	1.2	14.06	70.00	8.00	22.00	SANDY CLAY LOAM
28	SS14 (15-30)	0.8	<0.05	56.75	1.0	9.54	82.00	5.00	13.00	LOAM SAND
29	SS15 (0-15)	1.4	<0.05	57.90	1.3	25.22	68.00	19.00	13.00	SANDY LOAM
30	SS15 (15-30)	<0.1	<0.05	48.12	1.3	5.45	22.40	65.00	12.60	SILT LOAM
31	SS16 (0-15)	<0.1	<0.05	48.32	1.1	16.43	82.00	1.00	17.00	SANDY LOAM
32	SS16 (15-30)	0.4	<0.05	47.37	1.5	14.64	97.20	0.80	2.00	SAND
33	SS17 (0-15)	1.2	<0.05	45.18	1.2	9.68	52.6	12.9	34.50	SANDY LOAM

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S/N	FIELD CODE	THC (mg/kg)	Phenol (mg/kg)	Porosity (% pore space)	Permeability (K-4 cm/hr)	Cl- (mg/kg)	% Sand	% Silt	% Clay	Texture
34	SS17 (15-30)	0.6	<0.05	39.52	1.4	13.69	53.6	22.4	24.00	SANDY LOAM
35	SS18 (0-15)	0.8	<0.05	56.67	1.2	22.96	84.30	3.90	11.80	SAND
36	SS18 (15-30)	0.3	<0.05	54.25	1.1	28.55	85.90	7.20	6.90	SAND
37	SS19 (0-15)	0.2	<0.05	38.52	1.0	18.71	69.90	8.10	22.00	LOAM SAND
38	SS19 (15-30)	0.7	<0.05	42.91	1.2	10.04	79.90	6.60	13.50	LOAMY SAND
39	SS20 (0-15)	0.9	<0.05	34.30	1.4	13.26	88.00	3.70	8.30	SAND
40	SS20 (15-30)	0.6	<0.05	32.30	0.8	10.40	88.00	1.00	11.00	LOAM SAND
41	SS21 (0-15)	1.2	<0.05	45.13	1.2	15.86	82.00	1.00	17.00	SANDY LOAM
42	SS21 (15-30)	0.5	<0.05	47.25	1.5	12.91	85.00	3.00	12.00	LOAM SAND
43	SS22 (0-15)	<0.1	<0.05	38.30	0.7	33.24	86.50	7.00	6.50	SAND
44	SS22 (15-30)	<0.1	<0.05	59.09	0.9	40.89	81.60	11.00	7.40	LOAMY SAND
45	SS23 (0-15)	0.4	<0.05	56.15	1.2	13.59	58.20	17.60	24.20	SANDY LOAM
46	SS23 (15-30)	1.5	<0.05	38.14	1.1	17.45	80.90	9.70	9.40	LOAMY SAND
47	SS24 (0-15)	0.7	<0.05	45.22	0.9	16.30	56.20	17.40	26.40	SANDY LOAM
48	SS24 (15-30)	1.1	<0.05	37.50	0.8	8.09	75.10	20.10	4.80	LOAMY SAND
49	SS25 (0-15)	1.0	<0.05	44.29	1.3	12.65	54.90	22.70	22.40	SANDY LOAM
50	SS25 (15-30)	1.8	<0.05	53.12	1.1	8.44	85.00	3.00	12.00	LOAM SAND
51	SS26 (0-15)	0.7	<0.05	40.14	1.1	16.04	87.00	4.00	9.00	LOAM SAND

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S/N	FIELD CODE	THC (mg/kg)	Phenol (mg/kg)	Porosity (% pore space)	Permeability (K-4 cm/hr)	Cl- (mg/kg)	% Sand	% Silt	% Clay	Texture
52	SS26 (15-30)	0.9	<0.05	52.24	1.8	26.50	87.00	1.00	12.00	LOAM SAND
53	SS27 (0-15)	1.4	<0.05	54.43	0.6	7.32	56.90	10.80	32.30	SANDY LOAM
54	SS27 (15-30)	1.1	<0.05	37.14	1.6	10.40	58.30	23.20	18.50	SANDY LOAM
55	SS28 (0-15)	1.4	<0.05	59.24	1.3	17.78	51.50	19.30	29.20	SANDY LOAM
56	SS28 (15-30)	1.2	<0.05	44.34	1.7	35.14	16.90	14.10	69.00	CLAY LOAM
57	SS29 (0-15)	0.8	<0.05	56.78	1.5	26.88	73.00	2.00	25.00	SANDY CLAY LOAM
58	SS29 (15-30)	0.8	<0.05	43.14	1.2	43.59	63.90	0.25	35.86	SANDY LOAM
59	SS30 (0-15)	<0.1	<0.05	45.72	1.2	12.84	76.00	8.00	16.00	SANDY LOAM
60	SS30 (15-30)	1.4	<0.05	51.25	1.5	12.09	50.90	6.90	42.20	SANDY LOAM
61	SS31 (0-15)	1.0	<0.05	44.73	0.9	27.59	43.30	31.40	25.30	SANDY LOAM
62	SS31 (15-30)	0.8	<0.05	47.88	1.3	18.33	48.10	11.30	40.60	SANDY LOAM
63	SS32 (0-15)	0.4	<0.05	47.78	1.1	4.06	39.10	9.80	51.10	SANDY LOAM
64	SS32 (15-30)	1.0	<0.05	37.50	1.4	27.54	46.70	20.80	32.50	SANDY LOAM
65	SS33 (0-15)	1.3	<0.05	52.48	1.4	25.22	8.00	60.30	31.70	SILT LOAM
66	SS33 (15-30)	0.3	<0.05	61.42	1.8	17.45	90.40	7.20	2.40	SAND
67	SS34 (0-15)	0.8	<0.05	50.93	1.1	16.43	93.90	0.90	5.20	SAND
68	SS34 (15-30)	1.2	<0.05	43.37	0.7	4.64	92.40	7.30	0.30	SAND

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69	SS35 (0-15)	0.4	<0.05	48.26	1.3	25.68	94.50	1.20	4.30	SAND
70	SS35 (15-30)	0.4	<0.05	41.95	1.1	23.69	52.3	20.1	27.6	SANDY LOAM
71	SS36 (0-15)	0.5	<0.05	40.37	1.8	12.96	72.6	15.2	12.2	SANDY LOAM
72	SS36 (15-30)	0.7	<0.05	44.43	1.9	28.55	66.7	13.1	20.2	SANDY LOAM
73	SS37 (0-15)	0.4	<0.05	56.95	1.8	8.71	87.00	7.00	6.00	LOAM SAND
74	SS37 (15-30)	1.9	<0.05	48.34	1.1	10.04	88.00	4.00	8.00	SAND
75	SS38 (0-15)	0.4	<0.05	36.70	1.2	53.26	75.90	5.40	18.70	LOAMY SAND
76	SS38 (15-30)	1.3	<0.05	38.50	1.4	13.40	49.20	14.00	36.80	SANDY LOAM
77	SS39 (0-15)	0.3	<0.05	46.37	1.0	5.86	67.40	12.60	20.00	SANDY LOAM
78	SS39 (15-30)	0.6	<0.05	51.25	1.4	12.91	68.00	9.00	23.00	SANDY CLAY LOAM
79	SS40 (0-15)	0.3	<0.05	47.32	1.5	13.24	87.00	1.00	12.00	LOAM SAND
80	SS40 (15-30)	0.5	<0.05	49.31	1.2	10.89	59.40	22.50	18.10	SANDY LOAM
81	SS41 (0-15)	0.8	<0.05	53.80	1.1	53.59	58.10	17.10	24.80	SANDY LOAM
82	SS41 (15-30)	0.9	<0.05	37.50	1.8	17.45	62.30	21.50	16.20	SANDY LOAM
83	SS42 (0-15)	1.0	<0.05	44.30	1.6	26.30	66.10	18.00	15.90	LOAMY SAND
84	SS42 (15-30)	1.4	<0.05	32.90	1.4	8.09	75.00	20.50	4.50	LOAMY SAND

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S/N	FIELD CODE	THC (mg/kg)	Phenol (mg/kg)	Porosity (% pore space)	Permeability (K-4 cm/hr)	Cl- (mg/kg)	% Sand	% Silt	% Clay	Texture
85	SS43 (0-15)	0.5	<0.05	38.60	1.1	10.65	50.00	25.10	24.90	SAND LOAM
86	SS43 (15-30)	<0.1	<0.05	35.70	1.3	7.44	69.66	3.19	27.15	SANDY CLAY LOAM
87	SS44 (0-15)	1.2	<0.05	27.40	1.2	16.04	60.52	4.75	34.73	SANDY CLAY LOAM
88	SS44 (15-30)	1.2	<0.05	20.00	1.1	16.50	65.36	9.20	25.38	SANDY CLAY LOAM
89	SS45 (0-15)	1.4	<0.05	38.00	1.8	20.32	24.80	43.90	31.30	SILT LOAM
90	SS45 (15-30)	<0.1	<0.05	36.70	0.9	13.40	79.00	11.00	10.00	SANDY LOAM
91	SS46 (0-15)	1.1	<0.05	50.00	1.1	27.78	78.00	7.00	15.00	SANDY LOAM
92	SS46 (15-30)	0.8	<0.05	38.50	1.3	15.14	78.00	7.00	15.00	SANDY LOAM
93	SS47 (0-15)	0.4	<0.05	55.60	0.9	6.88	19.40	32.60	48.00	SILT LOAM
94	SS47 (15-30)	0.9	<0.05	39.60	1.2	13.59	39.30	31.10	29.60	LOAM
95	SS48 (0-15)	0.6	<0.05	44.00	1.2	22.84	61.30	11.50	27.20	SANDY LOAM
96	SS48 (15-30)	1.6	<0.05	49.09	0.8	10.09	82.78	3.19	15.99	SANDY LOAM
97	SS49 (0-15)	0.7	<0.05	42.86	1.2	7.59	81.00	6.00	13.00	SANDY LOAM
98	SS49 (15-30)	0.3	<0.05	47.70	0.8	48.33	40.40	35.20	24.40	LOAM
99	SS50 (0-15)	1.8	<0.05	35.00	0.8	14.06	82.00	0.00	18.00	SANDY LOAM

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S/N	FIELD CODE	THC (mg/kg)	Phenol (mg/kg)	Porosity (% pore space)	Permeability (K-4 cm/hr)	Cl- (mg/kg)	% Sand	% Silt	% Clay	Texture
100	SS50 (15-30)	1.0	<0.05	27.30	1.4	17.54	51.30	33.50	15.20	SANDY LOAM
101	SS51 (0-15)	1.0	<0.05	53.50	1.2	15.22	78.00	5.00	17.00	SANDY LOAM
102	SS51 (15-30)	1.3	<0.05	51.50	1.0	5.45	53.00	34.00	13.00	SANDY LOAM
103	SS52 (0-15)	0.3	<0.05	48.50	1.4	16.43	77.00	9.00	14.00	SANDY LOAM
104	SS52 (15-30)	0.7	<0.05	42.80	1.4	14.64	83.00	3.00	14.00	SANDY LOAM
105	SS53 (0-15)	0.7	<0.05	38.10	1.2	10.68	93.70	2.00	4.30	SAND
106	SS53 (15-30)	<0.1	<0.05	44.70	0.8	13.69	57.90	13.90	28.20	SANDY LOAM
107	SS54 (0-15)	0.9	<0.05	35.80	1.8	42.96	90.50	1.40	8.10	SAND
108	SS54 (15-30)	1.2	<0.05	48.12	1.2	38.55	91.10	1.80	7.10	SAND
109	SS55 (0-15)	2.3	<0.05	45.36	1.0	18.71	87.30	1.40	11.30	LOAM SAND
110	SS55 (15-30)	2.0	<0.05	46.20	1.3	10.04	80.90	6.40	12.70	SANDY LOAM
111	SS56 (0-15)	1.6	<0.05	40.90	1.0	13.26	94.00	2.00	4.00	SAND
112	SS56 (15-30)	1.2	<0.05	35.14	1.1	13.40	55.70	13.60	30.70	SANDY CLAY LOAM
113	SS57 (0-15)	<0.1	<0.05	32.70	1.0	15.86	42.20	40.00	17.80	LOAM
114	SS57 (15-30)	2.3	<0.05	30.70	0.8	8.91	43.90	31.50	24.60	LOAM
115	SS58 (0-15)	0.4	<0.05	46.20	1.3	13.24	20.80	25.80	53.40	LOAM
116	SS58 (15-30)	0.3	<0.05	42.90	1.1	10.89	87.10	1.40	11.50	LOAM SAND
117	SS59 (0-15)	0.9	<0.05	52.70	1.6	13.59	39.30	41.30	19.40	LOAM
118	SS59 (15-30)	1.1	<0.05	42.90	0.9	7.45	85.40	5.30	9.30	LOAM SAND

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119	SS60 (0-15)	0.7	<0.05	34.72	1.2	16.30	54.30	25.10	20.60	SANDY LOAM
120	SS60 (15-30)	0.9	<0.05	48.51	1.0	28.09	75.20	20.20	4.60	LOAMY SAND
121	SS61 (0-15)	1.2	<0.05	32.40	1.1	10.65	84.60	42.00	26.60	SAND
122	SS61 (15-30)	1.2	<0.05	47.05	1.0	6.44	52.30	11.70	36.00	SANDY LOAM
123	SS62 (0-15)	0.7	<0.05	33.90	1.3	16.04	33.30	17.40	49.30	SANDY LOAM
124	SS62 (15-30)	1.8	<0.05	43.80	1.7	10.50	51.30	17.10	31.60	SANDY LOAM
125	SS63 (0-15)	0.6	<0.05	45.10	0.8	8.32	88.40	0.80	10.80	SANDY LOAM
126	SS63 (15-30)	1.4	<0.05	25.00	1.3	6.40	50.90	17.60	31.50	SANDY LOAM
127	SSC1 (0-15)	1.1	<0.05	49.50	1.0	67.78	87.50	0.65	11.80	SANDY LOAM
128	SSC1 (15-30)	1.0	<0.05	29.60	1.5	55.14	87.00	2.00	11.00	LOAMY SAND
129	SSC2 (0-15)	1.3	<0.05	26.20	1.1	14.88	87.60	0.40	12.00	LOAMY SAND
130	SSC2 (15-30)	0.7	<0.05	38.89	0.9	6.59	39.00	28.70	32.30	SANDY LOAM

Appendix 4.6.5.1 b:

Physicochemical measurement in soils of the study area during dry season

S/N	FIELD CODE	pH	ELECTRICAL CONDUCTIVITY (uS/cm)	TOC (O/O)	O & G (ppm)	NH4+ (mg/kg)	NO3- (mg/kg)	SO42- (mg/kg)	TOTAL PHOSPHOROUS (mg/kg)	TOTAL NITROGEN (O/O)	BULK DENSITY (g/cm)
1	SSC1 (0-15)cm	6.21	53.60	0.40	2.2	0.312	1.329	2.76	1.93	0.0019	0.13
2	SSC1 (15-30)cm	5.22	86.20	1.10	2.4	0.183	1.773	2.58	1.62	0.0016	0.42
3	SSC2(0-15)cm	5.62	81.80	0.09	4.6	0.312	3.102	3.04	1.22	0.0012	0.41
4	ssC2(15-30)cm	5.2`	36.60	0.44	1.6	0.183	2.659	3.29	1.62	0.0016	0.24
5	SS5 (0-15)cm	5.60	16.50	0.32	1.8	0.170	0.284	3.34	1.22	0.0012	0.19
6	SS5 (15-30)cm	6.76	50.00	0.15	2.2	0.196	1.064	4.56	1.42	0.0014	0.23
7	SS6 (0-15)cm	4.86	21.50	0.93	3.0	0.170	1.773	3.25	1.12	0.0011	0.53
8	SS6 (15-30)cm	6.40	53.30	0.12	3.9	0.196	2.216	2.62	1.73	0.0017	0.27
9	SS7 (0-15) cm	5.19	57.50	0.38	3.3	0.209	4.431	3.21	2.13	0.0021	0.42
10	SS7 (15-30) cm	3.80	24.10	0.24	2.4	0.170	3.988	3.63	2.43	0.0024	0.29
11	SS8 (0-15) cm	4.35	25.00	0.04	2.4	0.196	1.418	3.27	1.12	0.0011	0.72
12	SS8 (15-30) cm	4.17	36.20	0.96	1.5	0.183	0.319	3.96	1.02	0.0010	0.37
13	SS9 (0-15) cm	4.70	20.30	0.71	1.2	0.170	0.496	4.55	3.53	0.0035	0.48
14	SS9 (15-30) cm	6.28	21.30	0.85	0.8	0.157	0.035	3.62	1.12	0.0011	0.18
15	SS10 (0-15) cm	4.71	71.60	0.01	1.1	0.196	0.011	3.26	1.73	0.0017	0.62
16	SS10 (15-30) cm	4.27	40.30	0.24	1.3	0.157	0.018	2.54	1.93	0.0019	0.49
17	SS11 (0-15)cm	3.76	13.90	0.26	1.7	0.183	0.007	4.01	0.92	0.0009	0.31
18	SS11 (15-30) cm	4.72	10.20	0.24	1.3	0.221	0.106	3.72	1.02	0.0010	0.42
19	SS12 (0-15) cm	4.18	20.30	0.71	1.9	0.157	0.071	3.02	1.62	0.0016	0.23
20	SS12(15-30) cm	4.32	39.10	0.57	1.1	0.209	1.418	4.62	1.62	0.0016	0.45
21	SS13 (0-15) cm	5.22	29.40	0.78	1.3	0.157	1.773	3.63	2.63	0.0026	0.34
22	SS13 (15-30) cm	4.55	11.12	0.74	2.0	0.170	2.216	3.63	1.32	0.0013	0.53
23	SS14 (0-15) cm	3.78	22.40	0.26	1.1	0.260	0.106	3.19	1.02	0.0010	0.43
24	SS14(15-30) cm	4.76	25.70	0.69	0.9	0.170	0.106	2.51	1.22	0.0012	0.18
25	SS15 (0-15) cm	4.94	46.50	0.27	0.7	0.183	2.216	2.65	1.02	0.0010	0.28

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26	SS15 (15-30) cm	4.66	48.40	0.71	1.0	0.209	2.216	3.14	1.22	0.0012	0.46
27	SS16 (0-15) cm	5.40	30.70	0.28	2.4	0.196	1.773	3.16	1.52	0.0015	0.15
28	SS16 (15-30) cm	4.42	23.10	0.85	2.1	0.196	2.482	2.71	2.93	0.0029	0.23
29	SS17 (0-15) cm	4.61	49.50	0.31	0.8	0.157	2.659	3.17	2.33	0.0023	0.41
30	SS17 (15-30) cm	4.65	76.00	0.31	0.8	0.170	3.988	4.48	1.32	0.0013	0.46
31	SS24(0-15) cm	4.72	75.60	0.20	1.4	0.196	0.089	4.36	1.93	0.0019	0.29
32	SS24 (15-30) cm	4.82	84.40	0.13	1.2	0.157	2.659	3.54	1.02	0.0010	0.26
33	SS27 (0-15) cm	5.33	87.30	0.07	2.2	0.183	1.418	2.44	1.42	0.0014	0.38
34	SS27 (15-30) cm	5.45	39.20	0.88	1.6	0.170	3.102	3.16	2.73	0.0027	0.18
35	SS28 (0-15) cm	5.42	98.10	0.31	1.9	0.157	0.142	3.61	0.92	0.0009	0.27
36	SS28 (15-30) cm	4.72	101.30	0.98	2.4	0.196	0.230	5.83	3.63	0.0036	0.38
37	SS29 (0-15) cm	4.91	75.40	0.26	1.7	0.170	0.213	5.78	5.64	0.0055	0.19
38	SS29 (15-30) cm	5.62	71.40	0.69	1.1	0.157	0.160	2.92	2.73	0.0027	0.28
39	SS30 (0-15) cm	5.90	120.90	0.96	2.5	0.144	2.659	4.69	3.03	0.0030	0.74
40	SS30 (15-30) cm	5.20	23.50	0.93	1.1	0.209	2.482	3.87	1.12	0.0011	0.66
41	SS31 (0-15) cm	6.03	85.30	0.75	0.7	0.157	3.988	4.93	1.62	0.0016	0.42
42	SS31 (15-30) cm	5.15	63.80	0.44	0.5	0.196	0.496	2.78	1.12	0.0011	0.28
43	SS32(0-15) cm	4.27	73.50	0.54	1.3	0.170	0.514	2.77	1.02	0.0010	0.37
44	SS32 (15-30) cm	6.19	89.50	0.99	0.3	0.183	1.418	4.56	1.32	0.0013	0.12
45	SS33 (0-15) cm	6.52	18.40	0.56	1.1	0.209	1.064	2.46	0.82	0.0008	0.44
46	SS33 (15-30) cm	5.91	65.30	0.55	0.7	0.157	1.324	3.54	0.92	0.0009	0.21
47	SS34 (0-15) cm	5.26	70.40	1.10	2.1	0.170	3.046	2.92	2.73	0.0027	0.18
48	SS34 (15-30) cm	4.65	91.50	0.17	0.9	0.196	1.206	3.17	1.32	0.0013	0.13
49	SS36 (0-15) cm	5.22	61.70	0.58	1.7	0.183	1.819	3.62	1.83	0.0018	0.29
50	SS36 (15-30) cm	5.49	38.20	0.43	0.9	0.209	1.237	3.47	1.02	0.0010	0.25
51	SS37 (0-15) cm	6.16	53.90	0.13	1.5	0.157	1.244	2.59	2.33	0.0023	0.15
52	SS37 (15-30) cm	5.00	52.70	0.83	0.9	0.183	2.514	3.64	1.32	0.0013	0.11

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S/N	FIELD CODE	pH	ELECTRICAL CONDUCTIVITY (uS/cm)	TOC (O/O)	O & G (ppm)	NH4+ (mg/kg)	NO3- (mg/kg)	SO42- (mg/kg)	TOTAL PHOSPHOROUS (mg/kg)	TOTAL NITROGEN (O/O)	BULK DENSITY (g/cm)
53	SS38 (0-15) cm	4.70	85.40	0.22	1.3	0.196	1.047	3.62	1.22	0.0012	0.27
54	SS38 (15-30) cm	5.40	23.80	0.78	0.9	0.144	2.373	3.17	1.42	0.0014	0.43
55	SS39 (0-15) cm	5.62	90.70	0.55	1.5	0.170	1.635	3.88	2.73	0.0027	0.52
56	SS39 (15-30) cm	4.41	19.50	1.16	1.1	0.144	2.110	4.35	1.93	0.0019	0.34
57	SS40(0-15) cm	6.20	91.30	0.71	2.6	0.183	1.242	5.47	2.73	0.0027	0.26
58	SS40 (15-30) cm	7.20	41.10	0.32	1.4	0.170	1.353	3.85	1.93	0.0019	0.71
59	SS41(0-15) cm	4.28	46.80	0.23	1.3	0.183	2.496	4.35	2.73	0.0027	0.39
60	SS41(15-30) cm	4.60	41.30	0.17	2.4	0.170	1.064	2.92	2.53	0.0025	0.25
61	SS42 (0-15) cm	4.82	42.50	1.01	2.8	0.209	0.906	4.46	2.23	0.0022	0.32
62	SS42 (15-30)cm	4.11	49.20	0.55	0.9	0.157	0.789	2.41	1.22	0.0012	0.31
63	SS43 (0-15) cm	6.05	86.50	0.46	1.9	0.144	1.106	3.60	2.23	0.0022	0.29
64	SS43 (15-30) cm	4.25	38.50	0.92	1.3	0.183	1.260	3.67	3.43	0.0034	0.46
65	SS44 (0-15) cm	4.70	36.40	0.35	1.1	0.170	3.429	2.72	0.92	0.0009	0.14
66	SS44 (15-30) cm	6.01	37.20	0.21	0.7	0.183	2.124	4.34	1.93	0.0019	0.11
67	SS45 (0-15) cm	5.02	39.70	0.65	2.5	0.144	2.047	4.06	2.33	0.0026	0.15
68	SS45 (15-30) cm	4.20	83.10	0.72	1.2	0.196	0.390	5.62	2.03	0.0020	0.63
69	SS46 (0-15) cm	4.09	85.20	0.37	1.5	0.170	1.064	3.87	1.73	0.0017	0.47
70	SS46 (15-30) cm	6.30	74.60	0.81	2.8	0.157	1.418	3.91	5.13	0.0050	0.35
71	SS47 (0-15) cm	4.90	28.90	0.94	1.1	0.196	1.773	2.94	1.02	0.0010	0.27
72	SS47 (15-30) cm	4.87	58.80	0.56	1.2	0.183	1.773	2.43	5.03	0.0049	0.54
73	SS48 (0-15) cm	4.43	78.50	0.57	1.7	0.157	3.191	3.49	0.92	0.0029	0.32
74	SS48 (15-30) cm	5.04	61.80	0.72	2.0	0.144	1.773	2.48	3.13	0.0031	0.51
75	SS50 (0-15) cm	4.70	54.20	0.80	1.5	0.183	1.064	2.59	1.52	0.0015	0.42
76	SS50 (15-30) cm	4.75	53.90	1.87	1.3	0.209	1.773	3.05	6.04	0.0059	0.67
77	SS51 (0-15) cm	5.25	37.20	1.68	1.2	0.170	2.216	2.78	2.43	0.0024	0.48
78	SS51(15-30) cm	4.75	27.50	0.79	1.0	0.144	1.773	4.10	0.42	0.0004	0.36
79	SS53 (0-15) cm	4.15	69.50	0.94	2.6	0.170	2.482	3.67	3.63	0.0036	0.33

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S/N	FIELD CODE	pH	ELECTRICAL CONDUCTIVITY (uS/cm)	TOC (O/O)	O & G (ppm)	NH4+ (mg/kg)	NO3- (mg/kg)	SO42- (mg/kg)	TOTAL PHOSPHOROUS (mg/kg)	TOTAL NITROGEN (O/O)	BULK DENSITY (g/cm)
80	SS53 (15-30) cm	4.24	61.80	0.11	1.2	0.170	3.191	4.57	4.93	0.0048	0.47
81	SS56 (0-15) cm	4.35	55.30	0.17	0.5	0.196	2.127	2.68	9.45	0.0093	0.15
82	SS56 (15-30) cm	4.62	56.40	0.18	0.2	0.183	1.773	4.68	4.73	0.0047	0.55
83	SS57 (0-15) cm	4.76	62.30	0.04	1.5	0.157	1.064	5.87	3.03	0.0030	0.33
84	SS57 (15-30) cm	4.97	68.90	0.04	0.6	0.144	0.620	4.84	0.62	0.0036	0.28
85	SS58 (0-15) cm	5.16	24.10	0.04	2.5	0.170	0.355	4.62	0.92	0.0029	0.23
86	SS58 (15-30) cm	4.99	26.50	0.04	1.8	0.144	0.638	4.86	0.52	0.0015	0.36
87	SS59 (0-15)cm	5.04	38.50	0.19	1.1	0.170	0.372	2.43	0.62	0.0016	0.23
88	SS59 (15-30) cm	4.85	48.20	0.74	0.7	0.157	2.127	2.54	1.93	0.0019	0.34
89	SS60 (0-15) cm	3.62	73.90	0.45	2.5	0.183	2.216	2.65	1.73	0.0017	0.42
90	SS60 (15-30)cm	5.22	79.00	0.48	2.1	0.170	1.773	2.66	2.23	0.0022	0.41
91	SS61 (0-15) cm	5.25	109.60	0.61	1.3	0.196	1.064	2.63	0.22	0.0032	0.18
92	SS61 (15-30) cm	5.06	150.40	0.60	1.9	0.183	1.064	2.54	0.42	0.0014	0.25
93	SS62 (0-15) cm	6.00	48.10	0.18	0.4	0.157	1.773	2.48	4.33	0.0043	0.82
94	SS62 (15-30) cm	5.87	51.50	0.17	0.3	0.196	1.773	3.12	0.22	0.0012	0.47

Appendix 4.6.5.1b Contd.:

Physicochemical measurement in soils of the study area during dry season

S/N	FIELD CODE	THC (mg/kg)	Phenol (mg/kg)	Porosity (% pore space)	Permeability (K-4 cm/hr)	Cl- (mg/kg)	% Sand	% Silt	% Clay	Texture
1	SSC1 (0-15)cm	1.1	<0.05	56.70	1.6	13.69	74.0	14.0	12.0	LOAM SAND
2	SSC1 (15-30)cm	0.2	<0.05	53.40	1.9	25.79	77.0	13.2	9.8	LOAM SAND
3	SSC2(0-15)cm	0.4	<0.05	56.00	0.8	22.89	84.0	4.6	11.4	LOAM SAND
4	SSC2(15-30)cm	0.4	<0.05	58.20	1.7	9.77	74.0	2.2	23.8	LOAM SAND
5	SS5 (0-15)cm	<0.1	<0.05	55.81	1.0	4.14	89.7	1.3	9.0	SAND
6	SS5 (15-30)cm	0.3	<0.05	49.83	1.5	16.55	84.8	7.1	8.1	LOAM SAND
7	SS6 (0-15)cm	1.1	<0.05	42.53	1.2	8.72	85.8	6.4	7.8	SAND
8	SS6 (15-30)cm	0.4	<0.05	50.53	1.9	21.27	73.8	6.5	19.7	LOAM SAND
9	SS7 (0-15) cm	<0.1	<0.05	55.80	1.1	18.43	73.5	7.0	19.5	LOAM SAND
10	SS7 (15-30) cm	<0.1	<0.05	55.80	2.0	7.59	72.9	8.3	18.8	LOAM SAND
11	SS8 (0-15) cm	0.4	<0.05	49.40	1.7	8.53	66.2	11.4	22.4	SANDY LOAM
12	SS8 (15-30) cm	0.7	<0.05	48.50	1.6	8.24	74.3	2.0	23.7	LOAM SAND
13	SS9 (0-15) cm	<0.1	<0.05	55.80	2.3	9.18	72.1	5.5	22.4	LOAM SAND
14	SS9 (15-30) cm	0.8	<0.05	44.40	1.6	8.26	94.6	0.8	4.6	SAND
15	SS10 (0-15) cm	0.5	<0.05	50.20	1.9	23.28	77.9	4.1	18.0	LOAM SAND
16	SS10 (15-30) cm	<0.1	<0.05	55.00	1.8	6.58	76.5	6.4	17.1	LOAM SAND
17	SS11 (0-15)cm	<0.1	<0.05	55.10	1.4	5.56	76.5	4.9	18.6	LOAM SAND
18	SS11 (15-30) cm	<0.1	<0.05	53.70	1.5	4.54	71.8	5.5	22.7	LOAM SAND

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S/N	FIELD CODE	THC (mg/kg)	Phenol (mg/kg)	Porosity (% pore space)	Permeability (K-4 cm/hr)	Cl- (mg/kg)	% Sand	% Silt	% Clay	Texture
19	SS12 (0-15) cm	<0.1	<0.05	43.20	1.2	7.65	86.6	1.9	11.5	SAND
20	SS12(15-30) cm	<0.1	<0.05	58.90	1.3	5.19	85.4	2.3	12.3	SAND
21	SS13 (0-15) cm	<0.1	<0.05	51.80	1.9	10.71	71.6	10.4	18.0	LOAM SAND
22	SS13 (15-30) cm	<0.1	<0.05	47.80	1.1	2.97	73.2	9.2	17.6	LOAM SAND
23	SS14 (0-15) cm	0.6	<0.05	41.10	1.8	8.93	71.6	11.3	17.1	LOAM SAND
24	SS14(15-30) cm	0.3	<0.05	55.70	0.7	7.96	72.3	10.1	17.6	LOAM SAND
25	SS15 (0-15) cm	0.5	<0.05	55.80	2.1	5.27	95.6	2.4	2.0	SAND
26	SS15 (15-30) cm	0.9	<0.05	56.70	2.1	7.45	91.9	1.8	6.3	SAND
27	SS16 (0-15) cm	1.2	<0.05	45.80	1.4	12.48	70.1	18.1	11.8	SANDY LOAM
28	SS16 (15-30) cm	0.9	<0.05	50.40	1.8	8.52	73.5	13.2	13.3	SANDY LOAM
29	SS17 (0-15) cm	1.4	<0.05	49.80	1.6	10.17	69.0	15.5	15.5	SANDY LOAM
30	SS17 (15-30) cm	0.8	<0.05	51.20	0.9	15.46	69.4	10.8	19.8	SANDY LOAM
31	SS24(0-15) cm	<0.1	<0.05	50.10	0.7	17.21	66.6	16.4	17.0	SANDY LOAM
32	SS24 (15-30) cm	0.4	<0.05	54.50	1.1	15.66	61.1	15.3	23.6	SANDY LOAM
33	SS27 (0-15) cm	1.4	<0.05	42.40	0.5	18.63	63.9	17.1	19.0	SANDY LOAM
34	SS27 (15-30) cm	1.5	<0.05	59.30	1.5	7.02	87.7	3.7	8.6	SAND
35	SS28 (0-15) cm	0.9	<0.05	53.20	0.8	18.07	97.7	0.5	1.8	SAND
36	SS28 (15-30) cm	0.3	<0.05	44.80	1.3	22.22	97.9	0.3	1.8	SAND
37	SS29 (0-15) cm	1.4	<0.05	52.40	1.2	17.39	88.5	2.2	9.3	SAND
38	SS29 (15-30) cm	2.3	<0.05	56.90	1.5	19.49	91.4	0.9	7.7	SAND
39	SS30 (0-15) cm	2.2	<0.05	49.60	1.0	48.86	91.1	1.8	7.1	SAND

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40	SS30 (15-30) cm	2.4	<0.05	49.90	1.2	7.40	64.8	12.4	22.8	SANDY LOAM
41	SS31 (0-15) cm	0.5	<0.05	45.40	1.7	16.88	67.2	13.7	19.1	SANDY LOAM
42	SS31 (15-30) cm	0.9	<0.05	40.90	1.8	14.59	67.0	10.5	22.5	SANDY LOAM
43	SS32(0-15) cm	<0.1	<0.05	57.90	1.1	23.72	79.9	0.4	19.7	SAND
44	SS32 (15-30) cm	<0.1	<0.05	52.20	1.3	24.40	89.5	0.2	10.3	SAND
45	SS33 (0-15) cm	0.7	<0.05	50.69	1.0	3.99	69.7	10.9	19.4	SANDY LOAM
46	SS33 (15-30) cm	0.8	<0.05	59.10	0.7	18.66	62.3	18.5	19.2	SANDY LOAM
47	SS34 (0-15) cm	0.4	<0.05	52.20	1.7	19.67	90.9	1.8	7.3	SAND
48	SS34 (15-30) cm	0.7	<0.05	45.40	1.3	19.10	95.0	2.0	3.0	SAND
49	SS36 (0-15) cm	0.2	<0.05	49.90	0.4	14.61	91.8	1.3	6.9	SAND
50	SS36 (15-30) cm	<0.1	<0.05	46.40	1.4	12.69	92.9	1.5	5.6	SAND
51	SS37 (0-15) cm	<0.1	<0.05	55.50	1.2	16.98	93.0	1.5	5.5	SAND
52	SS37 (15-30) cm	<0.1	<0.05	43.00	1.9	16.58	87.5	1.5	11.0	SAND
53	SS38 (0-15) cm	0.2	<0.05	55.70	1.0	15.00	89.1	1.0	9.9	SAND
54	SS38 (15-30) cm	0.4	<0.05	50.17	1.5	9.97	87.4	3.7	8.9	SAND
55	SS39 (0-15) cm	0.8	<0.05	44.30	1.2	32.21	80.7	7.3	12.0	LOAM SAND
56	SS39 (15-30) cm	0.4	<0.05	44.10	1.9	4.97	91.4	2.3	6.3	SAND
57	SS40(0-15) cm	0.4	<0.05	49.20	1.0	13.71	89.00	4.2	6.8	SAND
58	SS40 (15-30) cm	1.3	<0.05	44.92	1.3	9.49	82.30	5.4	12.3	LOAM SAND
59	SS41(0-15) cm	1.5	<0.05	58.20	0.8	8.93	89.50	4.8	5.7	SAND
60	SS41(15-30) cm	1.1	<0.05	51.00	1.3	12.53	75.20	16.1	8.7	SAND
61	SS42 (0-15) cm	0.5	<0.05	51.80	1.0	13.96	87.40	6.3	6.3	SAND
62	SS42 (15-30)cm	1.4	<0.05	52.52	0.6	18.88	92.10	4.2	3.7	SAND
63	SS43 (0-15) cm	1.7	<0.05	49.90	0.4	37.05	93.0	5.4	1.6	SAND

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64	SS43 (15-30) cm	0.9	<0.05	53.90	0.7	15.52	91.3	2.6	6.1	SAND
65	SS44 (0-15) cm	1.3	<0.05	53.72	1.2	4.74	89.8	1.6	8.6	SAND
66	SS44 (15-30) cm	0.5	<0.05	50.03	1.0	5.46	91.6	3.0	5.4	SAND
67	SS45 (0-15) cm	0.8	<0.05	43.00	0.9	8.94	85.5	4.2	10.3	LOAM SAND
68	SS45 (15-30) cm	1.2	<0.05	58.20	0.9	27.29	31.7	21.7	46.6	CLAY LOAM
69	SS46 (0-15) cm	<0.1	<0.05	54.70	1.3	23.20	59.0	27.2	13.8	SANDY LOAM
70	SS46 (15-30) cm	<0.1	<0.05	48.94	1.1	17.02	85.6	6.4	8.0	LOAM SAND
71	SS47 (0-15) cm	<0.1	<0.05	46.50	1.3	10.20	80.1	5.3	14.6	LOAM SAND
72	SS47 (15-30) cm	<0.1	<0.05	55.90	1.2	15.92	83.6	2.6	13.8	LOAM SAND
73	SS48 (0-15) cm	<0.1	<0.05	49.56	1.2	29.12	85.7	4.7	9.6	LOAM SAND
74	SS48 (15-30) cm	<0.1	<0.05	46.10	1.1	19.49	82.30	6.4	11.3	LOAM SAND
75	SS50 (0-15) cm	<0.1	<0.05	43.50	0.5	14.29	87.50	3.8	8.7	SAND
76	SS50 (15-30) cm	<0.1	<0.05	50.15	0.8	14.40	46.50	26.9	26.6	CLAY LOAM
77	SS51 (0-15) cm	0.6	<0.05	54.50	0.9	5.79	37.20	41.1	21.7	LOAM
78	SS51(15-30) cm	0.9	<0.05	48.91	0.8	8.05	90.10	5.2	4.7	SAND
79	SS53 (0-15) cm	0.6	<0.05	50.90	1.8	18.72	89.2	2.4	8.4	SAND
80	SS53 (15-30) cm	0.3	<0.05	47.94	1.2	18.97	91.9	3.0	5.1	SAND
81	SS56 (0-15) cm	0.1	<0.05	54.10	1.1	11.05	82.6	1.9	15.5	LOAM SAND
82	SS56 (15-30) cm	<0.1	<0.05	49.78	1.3	17.29	86.30	7.20	6.50	LOAM SAND
83	SS57 (0-15) cm	0.8	<0.05	43.50	0.9	19.10	85.50	9.40	5.10	LOAM SAND
84	SS57 (15-30) cm	0.4	<0.05	55.97	0.8	28.24	92.50	1.50	6.00	SAND

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S/N	FIELD CODE	THC (mg/kg)	Phenol (mg/kg)	Porosity (% pore space)	Permeability (K-4 cm/hr)	Cl- (mg/kg)	% Sand	% Silt	% Clay	Texture
85	SS58 (0-15) cm	0.6	<0.05	44.40	1.3	10.75	85.30	6.60	8.10	LOAM SAND
86	SS58 (15-30) cm	<0.1	<0.05	48.88	1.7	7.39	74.60	18.10	7.30	SANDY LOAM
87	SS59 (0-15)cm	0.5	<0.05	46.20	1.1	8.32	54.00	21.60	24.40	SANDY CLAY LOAM
88	SS59 (15-30) cm	0.2	<0.05	49.50	0.5	8.38	84.50	3.80	11.70	SANDY LOAM
89	SS60 (0-15) cm	1.3	<0.05	55.50	0.9	19.08	19.60	30.40	50.00	CLAY
90	SS60 (15-30)cm	0.5	<0.05	47.23	1.5	19.84	24.60	53.40	22.00	SILTY LOAM
91	SS61 (0-15) cm	0.9	<0.05	44.40	1.1	30.87	76.40	6.10	17.50	SANDY LOAM
92	SS61 (15-30) cm	<0.1	<0.05	49.54	1.5	45.97	87.30	7.60	5.10	LOAM SAND
93	SS62 (0-15) cm	1.2	<0.05	54.52	1.3	8.38	31.20	47.50	21.30	LOAM
94	SS62 (15-30) cm	0.7	<0.05	55.77	1.5	19.79	34.50	41.40	24.10	LOAM

Appendix 4.6.5.2 a:

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Cation and heavy metal measurement in soils of the study area during wet season

S/ N	FIELD CODE	Na (meq/1 00g)	K (meq/1 00g)	Ca (meq/1 00g)	Mg (meq/1 00g)	Fe (mg/ kg)	Cu (mg/ kg)	Zn (mg/ kg)	V (mg/ kg)	Pb (mg/ kg)	Cd (mg/ kg)	Ni (mg/ kg)	Cr (mg/ kg)	As (mg/ kg)	Hg (mg/ kg)	Ba (mg/ kg)
1	SS1 (0-15)	28.042	10.783	11.694	19.408	3607 .41	2.22 0	21.4 19	<0.0 5	5.41 7	0.05 4	8.27 1	0.72 1	0.01 4	<0.0 5	<0.0 5
2	SS1 (15-30)	31.326	9.818	10.617	16.179	3461 .27	2.12 9	21.3 70	<0.0 5	4.47 4	0.05 2	6.83 6	0.60 1	0.01 2	<0.0 5	<0.0 5
3	SS2 (0-15)	32.147	10.174	6.749	4.573	1085 .16	0.65 1	26.8 57	<0.0 5	4.82 2	0.01 8	7.36 6	0.17 0	0.00 8	<0.0 5	<0.0 5
4	SS2 (15-30)	28.042	9.161	8.811	10.760	2811 .76	1.72 5	39.6 18	<0.0 5	3.83 1	0.04 2	5.85 7	0.40 0	0.01 1	<0.0 5	<0.0 5
5	SS3 (0-15)	30.613	9.533	6.073	2.545	1676 .21	1.01 8	41.3 39	<0.0 5	4.19 6	0.02 6	6.41 2	0.09 5	<0.0 01	<0.0 5	<0.0 5
6	SS3 (15-30)	25.686	10.071	9.314	12.268	1396 .92	0.84 5	34.0 82	<0.0 5	4.72 1	0.02 2	7.21 2	0.45 6	0.01 1	<0.0 5	<0.0 5
7	SS4 (0-15)	38.550	9.039	6.765	4.623	4339 .18	2.67 5	50.0 57	<0.0 5	3.71 3	0.06 4	5.67 7	0.17 2	0.00 8	<0.0 5	<0.0 5
8	SS4 (15-30)	38.130	7.101	10.110	14.657	2035 .60	1.24 2	21.4 51	<0.0 5	1.81 8	0.03 1	2.79 2	0.54 4	0.01 2	<0.0 5	<0.0 5
9	SS5 (0-15)	29.389	8.375	7.245	6.061	2808 .52	1.72 3	39.4 07	<0.0 5	3.06 4	0.04 2	4.68 8	0.22 5	0.00 9	<0.0 5	<0.0 5
10	SS5 (15-30)	30.843	9.507	6.102	2.634	1284 .34	0.77 5	44.4 40	<0.0 5	4.17 0	0.02 1	6.37 3	0.09 8	0.00 8	<0.0 5	<0.0 5
11	SS6 (0-15)	40.404	6.696	6.539	3.944	2602 .84	1.59 5	21.4 51	<0.0 5	1.42 3	0.03 9	2.19 0	0.14 6	<0.0 01	<0.0 5	<0.0 5
12	SS6 (15-30)	37.368	8.890	6.342	3.353	2259 .68	1.38 1	32.4 58	<0.0 5	3.56 7	0.03 5	5.45 5	0.12 5	0.00 8	<0.0 5	<0.0 5
13	SS7 (0-15)	31.554	5.920	11.383	18.476	3144 .09	1.93 2	39.6 67	<0.0 5	0.66 4	0.04 7	1.03 5	0.68 6	0.01 3	<0.0 5	<0.0 5
14	SS7 (15-30)	24.337	5.640	6.686	4.385	2023 .70	1.23 5	25.7 54	<0.0 5	0.39 1	0.03 1	2.61 8	0.16 3	0.00 8	<0.0 5	<0.0 5
15	SS8 (0-15)	32.781	6.641	5.647	1.267	3068 .32	1.88 4	28.5 78	<0.0 5	1.36 9	0.04 6	2.10 8	0.04 7	<0.0 01	<0.0 5	<0.0 5
16	SS8 (15-30)	34.573	5.965	6.714	4.467	2083 .23	1.27 2	29.9 75	<0.0 5	0.70 8	0.03 2	1.10 1	0.16 6	0.00 8	<0.0 5	<0.0 5

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17	SS9 (0-15)	22.257	6.983	7.379	6.462	1286.51	0.776	24.601	<0.05	1.703	0.021	2.617	0.240	0.009	<0.05	<0.05
18	SS9 (15-30)	33.076	7.526	9.950	14.178	2819.34	1.730	12.766	<0.05	2.234	0.043	3.425	0.527	0.012	<0.05	<0.05
19	SS10 (0-15)	22.787	6.364	6.297	3.217	1145.78	0.688	26.776	<0.05	1.098	0.019	1.695	0.119	0.008	<0.05	<0.05
20	SS10 (15-30)	36.070	5.630	7.207	5.948	948.77	0.566	16.467	<0.05	0.381	0.016	4.603	0.221	<0.001	<0.05	<0.05
21	SS11 (0-15)	17.860	8.283	6.484	3.779	1480.28	0.897	30.754	<0.05	2.974	0.023	4.552	0.140	0.008	<0.05	<0.05
22	SS11 (15-30)	17.860	6.066	6.579	4.062	1985.81	1.211	25.689	<0.05	0.807	0.031	1.252	0.151	0.008	<0.05	<0.05
23	SS12 (0-15)	19.793	6.632	7.711	7.461	3038.01	1.866	23.221	<0.05	1.361	0.046	2.095	0.277	<0.001	<0.05	<0.05
24	SS12 (15-30)	22.257	7.013	7.232	6.022	2099.47	1.282	8.853	<0.05	1.732	0.032	2.661	0.224	0.009	<0.05	<0.05
25	SS13 (0-15)	23.371	6.385	7.461	6.708	3527.30	2.170	54.749	<0.05	1.119	0.053	1.727	0.249	0.009	<0.05	<0.05
26	SS13 (15-30)	25.775	9.298	10.335	15.331	2042.44	4.979	122.463	<0.05	3.965	0.117	6.061	0.569	0.012	<0.05	<0.05
27	SS14 (0-15)	20.481	5.938	10.347	15.368	2061.93	4.991	122.755	<0.05	0.682	0.117	1.061	0.571	0.012	<0.05	<0.05
28	SS14 (15-30)	28.977	11.969	6.466	3.723	1964.16	1.198	31.306	<0.05	6.576	0.030	8.036	0.138	<0.001	<0.05	<0.05
29	SS15 (0-15)	32.386	8.255	6.120	2.685	1420.74	0.860	23.156	<0.05	2.946	0.023	4.510	0.100	0.008	<0.05	<0.05
30	SS15 (15-30)	30.826	7.707	5.734	1.530	815.62	0.483	14.081	<0.05	2.411	0.014	3.695	0.057	0.007	<0.05	<0.05
31	SS16 (0-15)	21.019	5.993	6.219	2.983	1576.62	0.957	25.494	<0.05	0.736	0.025	1.144	0.111	<0.001	<0.05	<0.05
32	SS16 (15-30)	24.224	10.262	10.232	1.939	1029.95	0.616	17.295	<0.05	4.908	0.017	7.497	0.072	0.007	<0.05	<0.05

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33	SS17 (0-15)	21.707	10.690	6.626	4.625	2436 .13	1.49 1	38.3 84	<0.0 5	5.32 6	0.03 7	8.13 4	0.17 2	0.00 8	<0.0 5	<0.0 5
34	SS17 (15-30)	19.481	5.839	21.717	6.378	3354 .10	2.06 2	52.1 51	<0.0 5	0.58 5	0.05 0	2.91 5	0.23 7	0.00 9	<0.0 5	<0.0 5
35	SS18 (0-15)	20.037	6.100	23.133	5.534	2912 .44	1.78 8	45.5 27	<0.0 5	0.84 1	0.04 4	1.30 3	0.20 6	<0.0 01	<0.0 5	<0.0 5
36	SS18 (15-30)	27.516	5.766	16.792	2.611	1381 .77	0.83 5	22.5 72	<0.0 5	0.51 4	0.02 2	4.80 6	0.09 7	0.00 8	<0.0 5	<0.0 5
37	SS19 (0-15)	27.028	5.466	17.207	3.221	1304 .91	0.78 7	27.3 61	<0.0 5	0.22 1	0.02 1	3.36 0	0.12 0	0.00 8	<0.0 5	<0.0 5
38	SS19 (15-30)	23.752	6.101	5.543	1.412	1301 .66	0.78 5	13.1 55	<0.0 5	0.84 1	0.02 1	1.30 4	0.05 2	0.00 7	<0.0 5	<0.0 5
39	SS20 (0-15)	26.181	6.533	5.397	18.596	1667 .55	1.01 3	148. 098	<0.0 5	1.26 4	0.02 6	1.94 7	0.69 1	0.01 3	<0.0 5	<0.0 5
40	SS20 (15-30)	22.245	6.410	7.065	2.547	2518 .40	1.54 2	22.0 68	<0.0 5	1.14 4	0.03 8	1.76 5	0.09 5	0.00 8	<0.0 5	<0.0 5
41	SS21 (0-15)	18.880	6.232	13.406	3.893	2633 .15	1.61 4	32.6 37	<0.0 5	0.96 9	0.04 0	1.49 9	0.14 5	0.00 8	<0.0 5	<0.0 5
42	SS21 (15-30)	20.660	6.375	19.381	3.940	2149 .27	1.31 3	33.0 10	<0.0 5	1.10 9	0.03 3	1.71 1	0.14 6	0.00 8	<0.0 5	<0.0 5
43	SS22 (0-15)	19.722	6.427	4.054	10.928	3214 .46	1.97 5	87.8 83	<0.0 5	1.16 0	0.04 8	1.78 9	0.40 6	0.01 1	<0.0 5	<0.0 5
44	SS22 (15-30)	20.715	5.774	9.344	3.155	1307 .08	0.78 9	26.8 41	<0.0 5	0.52 2	0.02 1	3.81 8	0.11 7	0.00 8	<0.0 5	<0.0 5
45	SS23 (0-15)	20.890	5.784	5.543	9.107	2504 .33	1.53 4	15.2 50	<0.0 5	0.53 2	0.03 8	2.83 3	0.06 2	0.00 7	<0.0 5	<0.0 5
46	SS23 (15-30)	18.032	5.390	9.125	0.496	2839 .91	1.74 2	5.96 4	<0.0 5	0.14 6	0.04 3	4.24 6	0.01 8	0.00 7	<0.0 5	<0.0 5
47	SS24 (0-15)	18.807	5.789	13.683	1.695	1307 .08	0.78 9	15.3 80	<0.0 5	0.53 7	0.02 1	2.84 1	0.06 3	0.00 7	<0.0 5	<0.0 5
48	SS24 (15-30)	19.852	6.054	5.616	2.489	2041 .02	1.24 5	21.6 14	<0.0 5	0.79 6	0.03 1	1.23 5	0.09 2	0.00 8	<0.0 5	<0.0 5

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49	SS25 (0-15)	21.545	7.324	6.406	6.299	2521.65	1.544	51.534	<0.05	2.037	0.038	3.125	0.234	<0.001	<0.005	<0.005
50	SS25 (15-30)	20.892	7.758	5.885	7.599	1593.94	0.967	61.746	<0.05	2.460	0.025	3.770	0.282	<0.001	<0.005	<0.005
51	SS26 (0-15)	18.736	7.525	2.141	6.901	1782.30	1.084	56.258	<0.05	2.233	0.028	3.423	0.256	<0.001	<0.005	<0.005
52	SS26 (15-30)	22.216	6.495	7.008	3.812	1875.39	1.142	32.004	<0.05	1.227	0.029	1.891	0.142	<0.001	<0.005	<0.005
53	SS27 (0-15)	18.826	6.579	5.722	4.064	1517.08	0.919	33.984	<0.05	1.309	0.024	2.016	0.151	0.008	<0.005	<0.005
54	SS27 (15-30)	16.077	5.739	5.657	1.544	727.93	0.429	14.194	<0.05	0.488	0.013	3.766	0.057	0.007	<0.005	<0.005
55	SS28 (0-15)	18.513	7.092	2.287	5.602	1662.14	1.010	46.063	<0.05	1.810	0.026	2.779	0.208	0.009	<0.005	<0.005
56	SS28 (15-30)	16.829	7.807	4.371	7.748	974.75	0.582	62.915	<0.05	2.509	0.016	3.843	0.288	0.009	<0.005	<0.005
57	SS29 (0-15)	40.636	6.185	6.390	2.882	1927.35	1.175	24.698	<0.05	0.924	0.030	1.429	0.107	0.008	<0.005	<0.005
58	SS29 (15-30)	59.988	6.512	7.912	3.864	1589.61	0.965	32.410	<0.05	1.243	0.025	1.917	0.143	0.008	<0.005	<0.005
59	SS30 (0-15)	19.484	6.749	9.027	4.575	1425.07	0.862	37.994	<0.05	1.475	0.023	2.269	0.170	0.008	<0.005	<0.005
60	SS30 (15-30)	15.745	7.589	17.829	7.093	967.05	0.266	57.768	<0.05	2.295	0.009	3.518	0.263	0.009	<0.005	<0.005
61	SS31 (0-15)	13.569	9.300	27.642	12.228	1417.60	3.968	98.095	<0.05	3.968	0.094	6.065	0.454	0.011	<0.005	<0.005
62	SS31 (15-30)	12.341	7.287	17.654	6.188	3254.51	2.000	50.657	<0.05	2.000	0.049	3.069	0.230	0.009	<0.005	<0.005
63	SS32 (0-15)	22.158	5.779	24.113	1.664	885.98	0.527	15.136	<0.05	0.527	0.015	3.825	0.062	0.007	<0.005	<0.005
64	SS32 (15-30)	19.133	6.095	6.485	2.611	1381.77	0.835	22.572	<0.05	0.835	0.022	1.295	0.097	0.008	<0.005	<0.005

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65	SS33 (0-15)	17.642	5.741	10.175	1.550	826.44	0.490	14.243	<0.05	0.490	0.014	3.769	0.058	0.007	<0.05	<0.05
66	SS33 (15-30)	17.596	9.659	6.042	13.305	2981.59	4.319	106.553	<0.05	4.319	0.102	6.600	0.494	0.011	<0.05	<0.05
67	SS34 (0-15)	22.826	9.917	11.851	14.078	1386.44	4.571	112.625	<0.05	4.571	0.108	6.983	0.523	0.012	<0.05	<0.05
68	SS34 (15-30)	17.865	6.712	14.864	4.461	2350.61	1.438	37.102	<0.05	1.438	0.036	2.213	0.166	0.008	<0.05	<0.05
69	SS35 (0-15)	16.113	15.648	17.386	1.269	679.22	0.398	12.035	<0.05	0.398	0.012	3.630	0.047	0.007	<0.05	<0.05
70	SS35 (15-30)	19.070	5.784	4.947	1.679	893.56	0.532	15.250	<0.05	0.532	0.015	5.833	0.062	0.007	<0.05	<0.05
71	SS36 (0-15)	17.562	8.163	6.542	8.817	1631.46	2.857	71.308	<0.05	2.857	0.068	4.373	0.327	0.010	<0.05	<0.05
72	SS36 (15-30)	18.515	5.874	14.361	1.947	1034.28	0.619	17.360	<0.05	0.619	0.017	5.966	0.072	0.007	<0.05	<0.05
73	SS37 (0-15)	16.802	6.434	7.589	3.628	1914.36	1.167	30.559	<0.05	1.167	0.030	1.800	0.135	0.008	<0.05	<0.05
74	SS37 (15-30)	15.449	5.794	14.139	1.710	909.80	0.542	15.493	<0.05	0.542	0.015	3.848	0.063	0.007	<0.05	<0.05
75	SS38 (0-15)	20.478	8.387	6.663	9.487	2982.19	3.075	76.568	<0.05	3.075	0.073	4.706	0.352	0.010	<0.05	<0.05
76	SS38 (15-30)	17.437	8.693	16.971	10.405	1462.83	3.374	83.776	<0.05	3.374	0.080	5.161	0.386	0.010	<0.05	<0.05
77	SS39 (0-15)	28.434	12.040	10.548	20.448	1721.65	6.646	162.644	<0.05	6.646	0.155	4.143	0.759	0.014	<0.05	<0.05
78	SS39 (15-30)	25.813	10.478	19.686	15.761	1267.61	5.119	125.840	<0.05	5.119	0.120	7.818	0.585	0.012	<0.05	<0.05
79	SS40 (0-15)	30.487	17.294	11.422	6.210	2266.42	2.008	50.836	<0.05	2.008	0.049	3.080	0.231	0.009	<0.05	<0.05
80	SS40 (15-30)	25.598	5.628	24.202	1.211	648.91	0.379	11.581	<0.05	0.379	0.012	4.601	0.045	0.007	<0.05	<0.05

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81	SS41 (0-15)	27.685	19.149	4.721	11.773	2179.45	3.820	94.523	<0.05	3.820	0.090	5.840	0.437	0.011	<0.05	<0.05
82	SS41 (15-30)	21.483	10.622	15.881	16.193	1493.85	5.260	129.233	<0.05	5.260	0.123	8.032	0.601	0.012	<0.05	<0.05
83	SS42 (0-15)	33.432	8.024	13.106	8.397	1411.71	2.720	68.012	<0.05	2.720	0.065	4.165	0.312	0.010	<0.05	<0.05
84	SS42 (15-30)	24.253	5.633	22.725	1.226	656.49	0.384	11.694	<0.05	0.384	0.012	5.608	0.046	0.007	<0.05	<0.05
85	SS43 (0-15)	39.787	8.754	4.777	10.589	2559.17	3.434	85.221	<0.05	3.434	0.082	5.252	0.393	0.010	<0.05	<0.05
86	SS43 (15-30)	37.657	11.158	21.265	17.802	3336.04	5.784	141.863	<0.05	5.784	0.135	8.830	0.661	0.013	<0.05	<0.05
87	SS44 (0-15)	44.790	19.118	29.374	11.680	3130.73	3.790	93.793	<0.05	3.790	0.090	5.794	0.434	<0.001	<0.05	<0.05
88	SS44 (15-30)	35.507	6.671	15.519	4.339	2286.75	1.398	36.144	<0.05	1.398	0.035	2.152	0.161	<0.001	<0.05	<0.05
89	SS45 (0-15)	30.000	5.619	16.910	1.185	634.84	0.371	11.370	<0.05	0.371	0.011	4.588	0.044	0.007	<0.05	<0.05
90	SS45 (15-30)	18.506	5.631	4.616	1.220	653.24	0.382	11.646	<0.05	0.382	0.012	5.605	0.045	0.007	<0.05	<0.05
91	SS46 (0-15)	18.506	7.494	4.753	6.808	3579.26	2.202	55.528	<0.05	2.202	0.053	3.377	0.253	0.009	<0.05	<0.05
92	SS46 (15-30)	11.761	6.140	26.530	2.747	1453.22	0.880	23.643	<0.05	0.880	0.023	1.363	0.102	<0.001	<0.05	<0.05
93	SS47 (0-15)	15.306	8.715	10.707	10.473	2498.55	3.396	84.312	<0.05	3.396	0.081	5.195	0.389	<0.001	<0.05	<0.05
94	SS47 (15-30)	17.381	8.252	10.814	9.084	1771.10	2.944	73.402	<0.05	2.944	0.070	4.506	0.337	0.010	<0.05	<0.05
95	SS48 (0-15)	17.145	7.103	15.400	5.636	2965.48	1.821	46.323	<0.05	1.821	0.045	2.795	0.209	0.009	<0.05	<0.05
96	SS48 (15-30)	16.974	9.810	21.962	13.758	1218.65	4.466	110.109	<0.05	4.466	0.105	6.824	0.511	0.012	<0.05	<0.05

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97	SS49 (0-15)	17.800	7.236	13.616	6.035	2174.40	1.950	49.456	<0.05	1.950	0.048	2.993	0.224	0.009	<0.05	<0.05
98	SS49 (15-30)	16.838	5.865	13.517	1.923	1021.29	0.611	17.165	<0.05	0.611	0.017	3.954	0.071	0.007	<0.05	<0.05
99	SS50 (0-15)	16.683	6.317	7.492	3.277	1730.34	1.052	27.799	<0.05	1.052	0.027	1.625	0.122	0.008	<0.05	<0.05
100	SS50 (15-30)	21.083	10.423	12.769	15.596	1181.00	5.065	124.541	<0.05	5.065	0.119	7.736	0.579	0.012	<0.05	<0.05
101	SS51 (0-15)	11.283	5.610	10.778	1.156	619.68	0.361	11.142	<0.05	0.361	0.011	3.573	0.043	0.007	<0.05	<0.05
102	SS51 (15-30)	12.096	10.762	4.504	16.613	1713.60	5.396	132.529	<0.05	5.396	0.126	8.240	0.617	0.013	<0.05	<0.05
103	SS52 (0-15)	10.976	8.126	14.741	8.703	1571.92	2.820	70.415	<0.05	2.820	0.067	4.317	0.323	<0.001	<0.05	<0.05
104	SS52 (15-30)	18.832	9.611	13.918	13.159	2904.73	4.271	105.401	<0.05	4.271	0.101	6.527	0.489	<0.001	<0.05	<0.05
105	SS53 (0-15)	16.171	9.350	11.279	12.377	2495.54	4.017	99.264	<0.05	4.017	0.095	6.139	0.460	0.011	<0.05	<0.05
106	SS53 (15-30)	19.284	8.078	18.234	8.561	1497.23	2.773	69.295	<0.05	2.773	0.066	4.246	0.318	0.010	<0.05	<0.05
107	SS54 (0-15)	17.034	10.628	13.362	16.210	2502.51	5.265	129.363	<0.05	5.265	0.123	8.040	0.602	0.012	<0.05	<0.05
108	SS54 (15-30)	18.096	5.857	13.170	1.898	1008.30	0.603	16.971	<0.05	0.603	0.017	3.941	0.070	0.007	<0.05	<0.05
109	SS55 (0-15)	17.800	9.522	7.396	12.892	1765.08	4.184	103.306	<0.05	4.184	0.099	6.395	0.479	0.011	<0.05	<0.05
110	SS55 (15-30)	20.579	6.188	10.240	2.892	1528.99	0.927	24.779	<0.05	0.927	0.024	1.435	0.107	0.008	<0.05	<0.05
111	SS56 (0-15)	20.818	6.288	11.271	3.190	1684.87	1.024	27.117	<0.05	1.024	0.026	1.582	0.118	0.008	<0.05	<0.05
112	SS56 (15-30)	24.174	11.512	12.431	18.864	1892.45	6.130	150.208	<0.05	6.130	0.143	9.357	0.701	0.013	<0.05	<0.05

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11 3	SS57 (0- 15)	16.595	9.959	13.515	14.205	1452 .48	4.61 2	113. 615	<0.0 5	4.61 2	0.10 8	7.04 6	0.52 8	0.01 2	<0.0 5	<0.0 5

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114	SS57 (15-30)	15.792	6.251	15.356	3.078	1626.42	0.987	26.241	<0.05	0.987	0.026	1.527	0.114	0.008	<0.05	<0.05
115	SS58 (0-15)	17.327	7.356	11.996	6.394	1362.76	2.068	52.281	<0.05	2.068	0.050	3.172	0.237	<0.001	<0.05	<0.05
116	SS58 (15-30)	14.318	7.941	24.919	8.149	1281.81	2.639	66.064	<0.05	2.639	0.063	4.042	0.303	0.010	<0.05	<0.05
117	SS59 (0-15)	10.584	11.763	31.758	19.617	2286.48	6.375	156.117	<0.05	6.375	0.149	9.730	0.728	<0.001	<0.05	<0.05
118	SS59 (15-30)	16.852	7.727	16.447	7.509	1946.23	2.431	61.031	<0.05	2.431	0.059	3.724	0.279	0.009	<0.05	<0.05
119	SS60 (0-15)	18.640	8.458	19.261	9.702	2094.77	3.145	78.256	<0.05	3.145	0.075	4.812	0.360	0.010	<0.05	<0.05
120	SS60 (15-30)	17.258	6.233	17.809	3.024	1598.27	0.970	25.818	<0.05	0.970	0.025	1.500	0.112	0.008	<0.05	<0.05
121	SS61 (0-15)	18.413	5.811	11.787	1.759	935.78	0.558	15.883	<0.05	0.558	0.016	3.873	0.065	0.007	<0.05	<0.05
122	SS61 (15-30)	14.810	5.497	6.856	0.819	443.23	0.251	8.496	<0.05	0.251	0.009	4.406	0.030	0.007	<0.05	<0.05
123	SS62 (0-15)	15.751	5.563	3.190	1.015	546.07	0.315	10.038	<0.05	0.315	0.010	3.503	0.038	<0.001	<0.05	<0.05
124	SS62 (15-30)	15.585	5.916	3.956	2.074	1100.32	0.660	18.351	<0.05	0.660	0.018	1.029	0.077	0.007	<0.05	<0.05
125	SS63 (0-15)	25.906	6.062	8.081	2.512	1329.81	0.803	21.792	<0.05	0.803	0.021	1.246	0.093	0.008	<0.05	<0.05
126	SS63 (15-30)	15.666	5.956	9.789	2.195	1164.19	0.700	19.308	<0.05	0.700	0.019	1.089	0.082	0.008	<0.05	<0.05
127	SSC1 (0-15)	15.715	6.362	8.556	3.413	1801.78	1.097	28.871	<0.05	1.097	0.028	1.693	0.127	0.008	<0.05	<0.05
128	SSC1 (15-30)	23.043	11.531	13.301	3.920	2067.00	1.262	32.848	<0.05	1.262	0.032	1.944	0.146	0.008	<0.05	<0.05
129	SSC2 (0-15)	27.891	8.404	15.275	9.539	2009.26	3.092	76.974	<0.05	3.092	0.074	4.731	0.354	0.010	<0.05	<0.05
130	SSC2 (15-30)	17.409	9.791	17.172	13.700	1688.34	4.448	109.654	<0.05	4.448	0.105	6.796	0.509	0.012	<0.05	<0.05

Appendix 4.6.5.2 b:

Cation and heavy metal measurement in soils of the study area during dry season

S/ N	FIELD CODE	Na (meq/100g)	K (meq/100g)	Ca (meq/100g)	Mg (meq/100g)	Fe (mg/kg)	Cu (mg/kg)	Zn (mg/kg)	V (mg/kg)	Pb (mg/kg)	Cd (mg/kg)	Ni (mg/kg)	Cr (mg/kg)	As (mg/kg)	Hg (mg/kg)	Ba (mg/kg)
1	SSC1 (0-15)cm	26.141	10.053	10.902	18.093	1472.45	2.097	20.034	<0.05	5.084	0.073	7.751	0.697	0.018	<0.05	<0.05
2	SSC1 (15-30)cm	29.203	9.154	9.899	15.083	1525.03	2.012	19.989	<0.05	4.203	0.071	6.409	0.585	0.012	<0.05	<0.05
3	SSC2(0-15)cm	29.968	9.486	6.293	4.265	2572.44	0.631	25.115	<0.05	4.528	0.040	6.905	0.182	0.011	<0.05	<0.05
4	ssC2(15-30)cm	26.141	8.541	8.215	10.032	2506.72	1.635	37.037	<0.05	1.092	0.059	1.672	0.397	0.033	<0.05	<0.05
5	SS5 (0-15)cm	28.538	8.889	5.663	2.374	1472.24	0.975	38.645	<0.05	0.929	0.060	1.424	0.111	0.035	<0.05	<0.05
6	SS5 (15-30)cm	23.946	9.390	8.684	11.437	1393.37	0.812	31.865	<0.05	1.059	0.054	1.622	0.449	<0.001	<0.05	<0.05
7	SS6 (0-15)cm	35.937	8.428	6.308	4.311	1599.31	2.522	46.790	<0.05	3.492	0.083	5.327	0.184	<0.001	<0.05	<0.05
8	SS6 (15-30)cm	35.545	6.621	9.426	13.665	1592.59	1.184	20.064	<0.05	1.722	0.053	2.632	0.532	<0.001	<0.05	<0.05
9	SS7 (0-15)cm	27.397	7.809	6.755	5.652	1783.62	1.633	36.840	<0.05	2.885	0.063	4.403	0.233	<0.001	<0.05	<0.05
10	SS7 (15-30)cm	28.752	8.864	5.690	2.457	1806.89	0.747	41.542	<0.05	3.919	0.043	5.977	0.115	0.003	<0.05	<0.05
11	SS8 (0-15)cm	37.665	6.244	6.098	3.679	2290.93	1.513	20.064	<0.05	1.049	0.041	1.607	0.160	<0.001	<0.05	<0.05
12	SS8 (15-30)cm	34.835	8.289	5.914	3.128	2242.32	1.314	30.348	<0.05	0.379	0.038	4.324	0.140	<0.001	<0.05	<0.05
13	SS9 (0-15)cm	29.415	5.520	10.613	17.224	2149.23	1.828	37.082	<0.05	3.356	0.055	5.120	0.664	0.017	<0.05	<0.05
14	SS9 (15-30)cm	22.688	5.259	6.234	4.089	2033.70	1.177	24.084	<0.05	0.644	0.067	0.990	0.175	0.016	<0.05	<0.05
15	SS10 (0-15)cm	30.559	6.193	5.266	1.183	2168.88	1.784	26.723	<0.05	1.204	0.048	1.842	0.067	0.015	<0.05	<0.05

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16	SS10 (15-30) cm	32.229	5.562	6.260	4.167	1866 .61	1.21 1	28.0 27	<0.0 5	1.29 4	0.06 6	1.98 0	0.17 8	0.03 2	<0.0 5	<0.0 5
17	SS11 (0-15)cm	20.749	6.511	6.880	6.026	1669 .42	0.74 8	23.0 07	<0.0 5	1.64 2	0.05 3	2.50 9	0.24 7	0.01 2	<0.0 5	<0.0 5
18	SS11 (15-30) cm	30.834	7.018	9.277	13.218	1511 .68	1.63 9	11.9 50	<0.0 5	3.72 8	0.13 2	5.68 6	0.51 5	<0.0 01	<0.0 5	<0.0 5
19	SS12 (0-15) cm	21.243	5.934	5.872	3.001	2339 .85	0.66 6	25.0 39	<0.0 5	0.66 0	0.13 3	1.01 5	0.13 5	0.03 1	<0.0 5	<0.0 5
20	SS12(15-30) cm	33.625	5.250	6.720	5.546	2221 .54	0.55 2	15.4 08	<0.0 5	0.38 8	0.05 2	2.46 9	0.23 0	<0.0 01	<0.0 5	<0.0 5
21	SS13 (0-15) cm	16.651	7.723	6.046	3.525	2260 .97	0.86 1	28.7 55	<0.0 5	2.80 2	0.04 5	4.27 6	0.15 4	<0.0 01	<0.0 5	<0.0 5
22	SS13 (15-30) cm	16.651	5.656	6.134	3.789	2260 .97	1.15 5	24.0 23	<0.0 5	0.77 7	0.05 2	1.19 3	0.16 4	<0.0 01	<0.0 5	<0.0 5
23	SS14 (0-15) cm	18.452	6.184	7.190	6.957	1629 .99	1.76 6	21.7 18	<0.0 5	1.61 5	0.04 3	2.46 8	0.28 2	<0.0 01	<0.0 5	<0.0 5
24	SS14(15-30) cm	20.749	6.539	6.743	5.616	1669 .42	1.22 1	8.29 5	<0.0 5	2.11 0	0.06 3	3.22 3	0.23 2	<0.0 01	<0.0 5	<0.0 5
25	SS15 (0-15) cm	21.787	5.954	6.956	6.255	1907 .94	2.05 1	51.1 73	<0.0 5	1.06 8	0.07 2	1.63 7	0.25 6	<0.0 01	<0.0 5	<0.0 5
26	SS15 (15-30) cm	24.028	8.669	9.636	14.293	1727 .66	4.67 5	64.4 36	<0.0 5	1.30 2	0.06 6	1.99 3	0.55 5	<0.0 01	<0.0 5	<0.0 5
27	SS16 (0-15) cm	19.093	5.537	9.647	14.328	1156 .75	4.68 6	24.7 09	<0.0 5	0.68 5	0.05 3	1.05 2	0.55 6	<0.0 01	<0.0 5	<0.0 5
28	SS16 (15-30) cm	27.013	11.159	6.029	3.473	1473 .44	1.14 2	29.2 71	<0.0 5	6.16 6	0.05 2	7.53 1	0.15 2	<0.0 01	<0.0 5	<0.0 5
29	SS17 (0-15) cm	30.191	7.697	5.706	2.505	2089 .18	0.82 6	21.6 57	<0.0 5	2.77 6	0.04 4	4.23 7	0.11 6	0.00 3	<0.0 5	<0.0 5
30	SS17 (15-30) cm	28.736	7.186	5.347	1.428	1653 .30	0.47 5	13.1 78	<0.0 5	2.27 6	0.03 6	3.47 5	0.07 6	0.00 3	<0.0 5	<0.0 5
31	SS24(0-15) cm	19.595	5.589	5.799	2.783	1528 .98	0.91 7	23.8 41	<0.0 5	0.71 1	0.04 6	1.09 2	0.12 7	0.03 6	<0.0 5	<0.0 5

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32	SS24 (15-30) cm	22.583	9.568	9.540	1.810	2403.04	0.599	16.182	<0.05	4.609	0.039	7.027	0.090	0.030	<0.05	<0.05
33	SS27 (0-15) cm	20.236	9.967	6.178	4.313	2454.65	1.416	35.884	<0.05	4.999	0.058	7.622	0.184	0.031	<0.05	<0.05
34	SS27 (15-30) cm	18.162	5.445	20.245	5.947	3338.85	1.950	48.746	<0.05	0.570	0.070	2.746	0.244	0.036	<0.05	<0.05
35	SS28 (0-15) cm	18.679	5.689	21.566	5.161	3339.16	1.693	42.558	<0.05	0.809	0.064	1.241	0.215	0.031	<0.05	<0.05
36	SS28 (15-30) cm	45.651	11.377	17.655	4.436	1333.92	0.804	21.111	<0.05	0.503	0.044	4.513	0.114	0.031	<0.05	<0.05
37	SS29 (0-15) cm	25.196	5.098	16.042	3.005	1362.98	0.759	25.585	<0.05	0.230	0.043	3.162	0.135	0.031	<0.05	<0.05
38	SS29 (15-30) cm	22.142	5.689	5.169	1.318	1520.59	0.757	12.314	<0.05	0.809	0.043	1.242	0.072	0.030	<0.05	<0.05
39	SS30 (0-15) cm	44.406	16.092	9.033	17.336	1617.05	0.970	38.386	<0.05	3.603	0.063	5.495	0.668	<0.001	<0.05	<0.05
40	SS30 (15-30) cm	20.738	5.978	6.588	2.376	1656.49	1.464	20.641	<0.05	3.943	0.048	6.014	0.112	0.026	<0.05	<0.05
41	SS31 (0-15) cm	17.601	5.811	12.499	3.631	1630.19	1.531	30.515	<0.05	4.434	0.044	6.761	0.158	0.020	<0.05	<0.05
42	SS31 (15-30) cm	19.260	5.944	18.068	3.675	2138.64	1.250	30.864	<0.05	1.353	0.060	2.070	0.160	0.011	<0.05	<0.05
43	SS32(0-15) cm	18.386	5.993	3.781	10.189	2475.21	1.869	32.130	<0.05	1.107	0.068	1.695	0.402	0.033	<0.05	<0.05
44	SS32 (15-30) cm	19.312	5.385	8.713	2.943	2462.07	0.760	25.100	<0.05	0.511	0.043	3.590	0.133	0.031	<0.05	<0.05
45	SS33 (0-15) cm	19.475	5.394	5.169	8.491	3327.49	1.456	14.271	<0.05	0.520	0.059	2.670	0.081	<0.001	<0.05	<0.05
46	SS33 (15-30) cm	16.811	5.026	8.508	0.465	2500.51	1.651	5.595	<0.05	0.160	0.063	3.990	0.040	<0.001	<0.05	<0.05
47	SS34 (0-15) cm	17.533	5.399	12.757	1.582	2188.23	0.760	14.392	<0.05	0.525	0.043	2.677	0.082	<0.001	<0.05	<0.05

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48	SS34 (15-30) cm	18.507	5.645	5.237	2.322	3328.08	1.187	20.216	<0.05	0.766	0.053	1.177	0.110	<0.001	<0.005	<0.005
49	SS36 (0-15) cm	20.086	6.829	5.973	5.874	2772.73	1.466	48.170	<0.05	1.926	0.059	2.942	0.242	<0.001	<0.005	<0.005
50	SS36 (15-30) cm	19.477	7.233	5.488	7.086	1322.95	0.927	57.710	<0.05	2.322	0.047	3.545	0.287	<0.001	<0.005	<0.005
51	SS37 (0-15) cm	17.467	7.016	1.998	6.435	1042.88	1.036	52.584	<0.05	2.109	0.049	3.221	0.263	<0.001	<0.005	<0.005
52	SS37 (15-30) cm	20.711	6.057	6.535	3.556	1393.57	1.090	29.923	<0.05	1.169	0.050	1.790	0.155	<0.001	<0.005	<0.005
53	SS38 (0-15) cm	17.551	6.135	5.336	3.791	1551.32	0.882	31.774	<0.05	1.246	0.046	1.907	0.164	0.015	<0.005	<0.005
54	SS38 (15-30) cm	14.989	5.352	5.275	1.442	1590.76	0.424	13.285	<0.05	0.479	0.035	3.542	0.077	0.015	<0.005	<0.005
55	SS39 (0-15) cm	17.259	6.613	2.134	5.224	1577.61	0.967	43.058	<0.05	1.714	0.048	2.619	0.218	0.016	<0.005	<0.005
56	SS39 (15-30) cm	15.689	7.280	4.077	7.225	1630.19	0.567	58.802	<0.05	2.367	0.038	3.614	0.292	0.016	<0.005	<0.005
57	SS40(0-15) cm	37.881	5.768	5.958	2.688	1617.05	1.121	23.098	<0.05	0.886	0.051	1.359	0.123	0.015	<0.005	<0.005
58	SS40 (15-30) cm	55.919	6.073	7.377	3.604	2037.71	0.924	30.303	<0.05	1.185	0.047	1.814	0.157	0.015	<0.005	<0.005
59	SS41(0-15) cm	18.164	6.294	8.417	4.267	2195.45	0.829	35.520	<0.05	1.401	0.044	2.143	0.182	0.015	<0.005	<0.005
60	SS41(15-30) cm	14.679	7.076	16.621	6.614	1222.68	0.272	53.994	<0.05	2.168	0.032	3.310	0.269	0.016	<0.005	<0.005
61	SS42 (0-15) cm	12.650	8.672	25.768	11.401	1827.38	3.730	91.670	<0.05	3.730	0.111	5.690	0.447	0.017	<0.005	<0.005
62	SS42 (15-30)cm	11.505	6.795	16.458	5.770	1147.63	1.892	47.351	<0.05	1.892	0.069	2.891	0.238	0.016	<0.005	<0.005
63	SS43 (0-15) cm	20.656	5.389	22.479	1.553	1509.33	0.515	14.164	<0.05	0.515	0.037	3.597	0.081	0.015	<0.005	<0.005

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64	SS43 (15-30) cm	17.837	5.683	6.048	2.436	2129 .89	0.80 4	21.1 11	<0.0 5	0.80 4	0.04 4	1.23 3	0.11 4	0.01 5	<0.0 5	<0.0 5
65	SS44 (0-15) cm	16.447	5.354	9.487	1.447	1074 .94	0.48 1	13.3 30	<0.0 5	0.48 1	0.03 6	3.54 5	0.07 7	0.01 5	<0.0 5	<0.0 5
66	SS44 (15-30) cm	16.404	9.006	5.634	12.405	1757 .55	4.05 8	19.5 72	<0.0 5	4.05 8	0.11 8	6.18 9	0.48 5	0.01 7	<0.0 5	<0.0 5
67	SS45 (0-15) cm	21.279	9.246	11.049	13.125	2191 .95	4.29 3	35.2 45	<0.0 5	4.29 3	0.12 4	6.54 7	0.51 2	0.01 7	<0.0 5	<0.0 5
68	SS45 (15-30) cm	16.655	6.258	13.858	4.161	1136 .99	1.36 7	34.6 86	<0.0 5	1.36 7	0.05 7	2.09 1	0.17 8	0.01 5	<0.0 5	<0.0 5
69	SS46 (0-15) cm	15.022	14.588	16.208	1.185	2191 .95	0.39 5	11.2 67	<0.0 5	0.39 5	0.03 4	3.41 4	0.06 7	0.01 5	<0.0 5	<0.0 5
70	SS46 (15-30) cm	17.779	5.394	4.613	1.567	3390 .97	0.52 0	14.2 71	<0.0 5	0.52 0	0.03 7	5.47 2	0.08 1	0.01 5	<0.0 5	<0.0 5
71	SS47 (0-15) cm	16.373	7.612	6.100	8.221	1901 .63	2.69 2	66.6 44	<0.0 5	2.69 2	0.08 7	4.10 9	0.32 9	0.01 6	<0.0 5	<0.0 5
72	SS47 (15-30) cm	17.261	5.477	13.388	1.817	2222 .97	0.60 2	16.2 42	<0.0 5	0.60 2	0.03 9	5.59 7	0.09 1	0.01 5	<0.0 5	<0.0 5
73	SS48 (0-15) cm	15.664	5.999	7.076	3.384	1881 .67	1.11 3	28.5 73	<0.0 5	1.11 3	0.05 1	1.70 5	0.14 9	0.01 5	<0.0 5	<0.0 5
74	SS48 (15-30) cm	14.403	5.403	13.182	1.596	2129 .89	0.52 9	14.4 98	<0.0 5	0.52 9	0.03 8	3.61 8	0.08 2	0.01 5	<0.0 5	<0.0 5
75	SS50 (0-15) cm	19.091	7.820	6.213	8.845	2347 .09	2.89 6	71.5 58	<0.0 5	2.89 6	0.09 2	4.42 0	0.35 2	0.01 6	<0.0 5	<0.0 5
76	SS50 (15-30) cm	16.256	8.105	15.822	9.701	1230 .08	3.17 5	78.2 92	<0.0 5	3.17 5	0.09 8	4.84 5	0.38 4	0.01 6	<0.0 5	<0.0 5
77	SS51 (0-15) cm	26.507	11.226	9.834	19.063	1509 .33	6.23 2	51.9 76	<0.0 5	6.23 2	0.16 8	3.89 3	0.73 3	0.01 8	<0.0 5	<0.0 5
78	SS51(15-30) cm	24.063	9.769	18.353	14.694	1788 .58	4.80 6	67.5 91	<0.0 5	4.80 6	0.13 5	7.32 7	0.57 0	0.03 2	<0.0 5	<0.0 5
79	SS53 (0-15) cm	28.421	16.123	10.649	5.791	1408 .62	1.89 9	47.5 18	<0.0 5	1.89 9	0.06 9	2.90 1	0.23 9	0.03 0	<0.0 5	<0.0 5

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80	SS53 (15-30) cm	23.863	5.249	22.561	1.131	1674.81	0.378	30.843	<0.05	0.378	0.034	4.322	0.065	<0.001	<0.05	<0.05
81	SS56 (0-15) cm	25.808	17.852	4.403	10.977	1598.08	3.592	88.333	<0.05	3.592	0.108	5.479	0.432	0.017	<0.05	<0.05
82	SS56 (15-30) cm	20.027	9.904	14.806	15.097	1271.45	4.937	90.761	<0.05	4.937	0.138	7.527	0.585	0.017	<0.05	<0.05
83	SS57 (0-15) cm	31.165	7.481	12.219	7.830	760.11	2.565	63.565	<0.05	2.565	0.084	3.915	0.315	0.016	<0.05	<0.05
84	SS57 (15-30) cm	22.609	5.253	21.185	1.145	679.01	0.382	50.949	<0.05	0.382	0.034	5.263	0.066	0.015	<0.05	<0.05
85	SS58 (0-15) cm	37.089	8.162	4.455	9.872	2646.89	3.231	59.642	<0.05	3.231	0.099	4.930	0.391	0.016	<0.05	<0.05
86	SS58 (15-30) cm	35.104	10.403	19.824	16.596	3450.38	5.427	52.562	<0.05	5.427	0.150	8.273	0.641	0.018	<0.05	<0.05
87	SS59 (0-15)cm	41.753	17.823	27.383	10.890	3238.04	3.564	47.651	<0.05	3.564	0.107	5.436	0.428	<0.001	<0.05	<0.05
88	SS59 (15-30) cm	33.100	6.220	14.468	4.047	2365.13	1.330	43.791	<0.05	1.330	0.056	2.034	0.174	<0.001	<0.05	<0.05
89	SS60 (0-15) cm	27.967	5.240	15.765	1.106	956.62	0.369	10.645	<0.05	0.369	0.034	4.309	0.064	<0.001	<0.05	<0.05
90	SS60 (15-30)cm	17.252	5.251	4.305	1.139	875.65	0.380	10.903	<0.05	0.380	0.034	5.260	0.065	0.015	<0.05	<0.05
91	SS61 (0-15) cm	27.252	6.987	4.433	6.348	2701.94	2.081	51.901	<0.05	2.081	0.073	3.178	0.259	0.016	<0.05	<0.05
92	SS61 (15-30) cm	10.965	15.726	24.732	2.563	2503.04	0.845	22.112	<0.05	0.845	0.045	1.296	0.119	<0.001	<0.05	<0.05
93	SS62 (0-15) cm	14.270	8.126	9.983	9.765	2584.19	3.196	48.793	<0.05	3.196	0.099	4.877	0.387	0.015	<0.05	<0.05
94	SS62 (15-30) cm	16.204	7.695	10.082	8.470	1831.82	2.773	48.600	<0.05	2.773	0.089	4.233	0.338	0.016	<0.05	<0.05

Appendix 4.6.5.3 a:

Hydrocarbons measurement in soils of the study area during wet season

COM PON ENT	Alip hatic	Polycyclic Aromatic Hydrocarbons																	
		nC8 - nC4 4	Naph thale ne	Acen aphth alene	Acen aphth ene	Flore ne	Phen athre ne	Anthr acene	Fluor anthe ne	Pyren e	Benz o(a)a nthra cene	Cryse ne	Benz o(b)fl uoran threne	Benz o(a)p yrene	Benz o(k)fl uoran threne	Inden o(1,2 ,3) peryl ene	Dibe nzo(a ,h)ant hrace ne	Benz o(g,h, i) peryl ene	Total PAH (mg/ kg)
SS1 (0- 15)	0.02 5	0.000	0.000	0.000	0.000	0.000	0.000	0.011	0.000	0.020	0.000	0.021	0.000	0.000	0.000	0.000	0.000	0.000	0.052
SS1 (15- 30)	0.02 7	0.000	0.000	0.000	0.013	0.000	0.000	0.012	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.026
SS2 (0- 15)	0.02 4	0.012	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.019	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.032
SS2 (15- 30)	0.01 4	0.000	0.010	0.011	0.000	0.000	0.000	0.016	0.019	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.056
SS3 (0- 15)	0.01 1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.020	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.020
SS3 (15- 30)	0.01 2	0.000	0.000	0.000	0.014	0.000	0.014	0.012	0.016	0.019	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.075
SS4 (0- 15)	0.02 5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.012	0.000	0.019	0.000	0.021	0.000	0.000	0.000	0.000	0.000	0.052
SS4 (15- 30)	0.01 8	0.003	0.002	0.002	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.011

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COM PON ENT	Alip hatic	Polycyclic Aromatic Hydrocarbons																
		Naph thale ne	Acen aphth alene	Acen aphth ene	Flore ne	Phen athre ne	Anthr acene	Fluor anthe ne	Pyren e	Benz o(a)a nthra cene	Cryse ne	Benz o(b)fl uoran threne	Benz o(a)p yrene	Benz o(k)fl uoran threne	Inden o(1,2 ,3) peryl ene	Dibe nzo(a ,h)ant hrace ne	Benz o(g,h, i) peryl ene	Total PAH (mg/ kg)
SS5 (0- 15)	0.02 8	0.002	0.003	0.008	0.002	0.003	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.020
SS5 (15- 30)	0.02 9	0.003	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.005
SS6 (0- 15)	0.01 6	0.000	0.000	0.000	0.011	0.000	0.000	0.000	0.000	0.019	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.030
SS6 (15- 30)	0.02 3	0.000	0.000	0.011	0.014	0.000	0.000	0.012	0.016	0.020	0.000	0.000	0.021	0.000	0.008	0.006	0.000	0.108
SS7 (0- 15)	0.01 6	0.000	0.010	0.010	0.000	0.000	0.000	0.000	0.016	0.019	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.055
SS7 (15- 30)	0.02 4	0.008	0.006	0.005	0.005	0.003	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.029
SS8 (0- 15)	0.02 1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	<0.00 1
SS8 (15- 30)	0.02 0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001

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		Naph thale ne	Acen aphth alene	Acen aphth ene	Flore ne	Phen athre ne	Anthr acene	Fluor anthe ne	Pyren e	Benz o(a)a nthra cene	Cryse ne	Benz o(b)fl uoran threne	Benz o(a)p yrene	Benz o(k)fl uoran threne	Inden o(1,2 ,3) peryl ene	Dibe nzo(a ,h)ant hrace ne	Benz o(g,h, i) peryl ene	Total PAH (mg/ kg)
SS9 (0- 15)	0.00 9	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001
SS9 (15- 30)	0.03 1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001
SS10 (0- 15)	0.01 7	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	<0.00 1
SS10 (15- 30)	0.01 8	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	<0.00 1
SS11 (0- 15)	0.01 7	0.000	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002
SS11 (15- 30)	0.05 1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	<0.00 1
SS12 (0- 15)	0.09 3	0.000	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002
SS12 (15- 30)	0.03 2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	<0.00 1

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		Naph thale ne	Acen aphth alene	Acen aphth ene	Flore ne	Phen athre ne	Anthr acene	Fluor anthe ne	Pyren e	Benz o(a)a nthra cene	Cryse ne	Benz o(b)fl uoran threne	Benz o(a)p yrene	Benz o(k)fl uoran threne	Inden o(1,2 ,3) peryl ene	Dibe nzo(a ,h)ant hrace ne	Benz o(g,h, i) peryl ene	Total PAH (mg/ kg)	
SS13 (0- 15)	0.05 8	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	<0.00 1
SS13 (15- 30)	0.04 2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	<0.00 1
SS14 (0- 15)	0.02 5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	<0.00 1
SS14 (15- 30)	0.08 4	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	<0.00 1
SS15 (0- 15)	0.12 7	0.000	0.006	0.000	0.000	0.000	0.043	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.048
SS15 (15- 30)	0.04 6	0.000	0.009	0.000	0.000	0.000	0.077	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.087
SS16 (0- 15)	0.00 7	0.000	0.010	0.000	0.000	0.000	0.077	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.087
SS16 (15- 30)	0.04 3	0.000	0.006	0.000	0.000	0.000	0.015	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.020

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		Naph thale ne	Acen aphth alene	Acen aphth ene	Flore ne	Phen athre ne	Anthr acene	Fluor anthe ne	Pyren e	Benz o(a)a nthra cene	Cryse ne	Benz o(b)fl uoran threne	Benz o(a)p yrene	Benz o(k)fl uoran threne	Inden o(1,2 ,3) peryl ene	Dibe nzo(a ,h)ant hrace ne	Benz o(g,h, i) peryl ene	Total PAH (mg/ kg)
SS17 (0- 15)	0.66 4	0.000	0.023	0.004	0.000	0.003	0.264	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.293
SS17 (15- 30)	0.21 6	0.000	0.008	0.000	0.000	0.000	0.065	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.073
SS18 (0- 15)	0.21 1	0.000	0.003	0.000	0.000	0.005	0.003	0.010	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.026
SS18 (15- 30)	0.20 4	0.000	0.004	0.000	0.000	0.000	0.035	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.039
SS19 (0- 15)	0.22 7	0.000	0.000	0.000	0.000	0.000	0.003	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.006
SS19 (15- 30)	0.63 9	0.000	0.274	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.274
SS20 (0- 15)	0.25 4	0.000	0.046	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.046
SS20 (15- 30)	0.33 9	0.002	0.024	0.004	0.000	0.007	0.212	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.251

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COM PON ENT	Alip hatic	Polycyclic Aromatic Hydrocarbons																
		Naph thale ne	Acen aphth alene	Acen aphth ene	Flore ne	Phen athre ne	Anthr acene	Fluor anthe ne	Pyren e	Benz o(a)a nthra cene	Cryse ne	Benz o(b)fl uoran threne	Benz o(a)p yrene	Benz o(k)fl uoran threne	Inden o(1,2 ,3) peryl ene	Dibe nzo(a ,h)ant hrace ne	Benz o(g,h, i) peryl ene	Total PAH (mg/ kg)
SS21 (0- 15)	0.17 9	0.001	0.000	0.001	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.003
SS21 (15- 30)	0.07 5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002
SS22 (0- 15)	0.05 4	0.000	0.001	0.001	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.004
SS22 (15- 30)	0.04 9	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002
SS23 (0- 15)	0.19 1	0.001	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.004
SS23 (15- 30)	0.01 2	0.001	0.001	0.001	0.004	0.001	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.008
SS24 (0- 15)	0.02 2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	<0.00 1
SS24 (15- 30)	0.02 9	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001

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COM PON ENT	Alip hatic	Polycyclic Aromatic Hydrocarbons																
		Naph thale ne	Acen aphth alene	Acen aphth ene	Flore ne	Phen athre ne	Anthr acene	Fluor anthe ne	Pyren e	Benz o(a)a nthra cene	Cryse ne	Benz o(b)fl uoran threne	Benz o(a)p yrene	Benz o(k)fl uoran threne	Inden o(1,2 ,3) peryl ene	Dibe nzo(a ,h)ant hrace ne	Benz o(g,h, i) peryl ene	Total PAH (mg/ kg)
SS25 (0- 15)	0.02 6	0.000	0.000	0.000	0.000	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002
SS25 (15- 30)	0.01 8	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001
SS26 (0- 15)	0.01 3	0.000	0.000	0.006	0.006	0.000	0.041	0.014	0.010	0.000	0.010	0.000	0.000	0.000	0.000	0.000	0.000	0.087
SS26 (15- 30)	0.02 8	0.000	0.000	0.000	0.006	0.000	0.015	0.000	0.007	0.000	0.012	0.000	0.000	0.000	0.000	0.000	0.000	0.040
SS27 (0- 15)	0.01 4	0.000	0.000	0.000	0.000	0.000	0.005	0.007	0.013	0.000	0.007	0.000	0.000	0.000	0.000	0.000	0.000	0.032
SS27 (15- 30)	0.01 5	0.000	0.000	0.005	0.003	0.000	0.003	0.009	0.009	0.006	0.008	0.000	0.000	0.000	0.000	0.000	0.000	0.042
SS28 (0- 15)	0.04 6	0.000	0.000	0.000	0.000	0.000	0.000	0.006	0.000	0.000	0.007	0.000	0.000	0.000	0.000	0.000	0.000	0.013
SS28 (15- 30)	0.03 7	0.008	0.011	0.031	0.007	0.011	0.007	0.006	0.022	0.084	0.007	0.000	0.000	0.000	0.000	0.000	0.000	0.195

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COM PON ENT	Alip hatic	Polycyclic Aromatic Hydrocarbons																
		Naph thale ne	Acen aphth alene	Acen aphth ene	Flore ne	Phen athre ne	Anthr acene	Fluor anthe ne	Pyren e	Benz o(a)a nthra cene	Cryse ne	Benz o(b)fl uoran threne	Benz o(a)p yrene	Benz o(k)fl uoran threne	Inden o(1,2 ,3) peryl ene	Dibe nzo(a ,h)ant hrace ne	Benz o(g,h, i) peryl ene	Total PAH (mg/ kg)
SS29 (0- 15)	0.03 1	0.000	0.001	0.001	0.001	0.002	0.001	0.001	0.004	0.007	0.001	0.000	0.003	0.000	0.000	0.000	0.000	0.021
SS29 (15- 30)	0.03 3	0.000	0.000	0.000	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.004
SS30 (0- 15)	0.03 8	0.000	0.000	0.000	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002
SS30 (15- 30)	0.02 3	0.000	0.000	0.000	0.002	0.002	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.005
SS31 (0- 15)	0.03 2	0.000	0.000	0.000	0.003	0.002	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.006
SS31 (15- 30)	0.03 7	0.000	0.000	0.000	0.003	0.003	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.007
SS32 (0- 15)	0.01 7	0.000	0.000	0.000	0.002	0.002	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.005
SS32 (15- 30)	0.00 5	0.000	0.001	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002

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COM PON ENT	Alip hatic	Polycyclic Aromatic Hydrocarbons																
		Naph thale ne	Acen aphth alene	Acen aphth ene	Flore ne	Phen athre ne	Anthr acene	Fluor anthe ne	Pyren e	Benz o(a)a nthra cene	Cryse ne	Benz o(b)fl uoran threne	Benz o(a)p yrene	Benz o(k)fl uoran threne	Inden o(1,2 ,3) peryl ene	Dibe nzo(a ,h)ant hrace ne	Benz o(g,h, i) peryl ene	Total PAH (mg/ kg)
SS33 (0- 15)	0.00 7	0.000	0.002	0.000	0.000	0.000	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.004
SS33 (15- 30)	0.02 2	0.000	0.002	0.000	0.000	0.000	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.004
SS34 (0- 15)	0.02 5	0.000	0.002	0.001	0.000	0.000	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.005
SS34 (15- 30)	0.01 8	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001
SS35 (0- 15)	0.01 6	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001
SS35 (15- 30)	0.01 2	0.000	0.003	0.001	0.000	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.005
SS36 (0- 15)	0.12 2	0.000	0.000	0.024	0.028	0.013	0.006	0.006	0.008	0.009	0.008	0.000	0.000	0.000	0.000	0.000	0.000	0.103
SS36 (15- 30)	0.06 3	0.000	0.000	0.020	0.021	0.011	0.000	0.000	0.000	0.018	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.071

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COM PON ENT	Alip hatic	Polycyclic Aromatic Hydrocarbons																
		Naph thale ne	Acen aphth alene	Acen aphth ene	Flore ne	Phen athre ne	Anthr acene	Fluor anthe ne	Pyren e	Benz o(a)a nthra cene	Cryse ne	Benz o(b)fl uoran threne	Benz o(a)p yrene	Benz o(k)fl uoran threne	Inden o(1,2 ,3) peryl ene	Dibe nzo(a ,h)ant hrace ne	Benz o(g,h ,i) peryl ene	Total PAH (mg/ kg)
SS37 (0- 15)	0.05 2	0.000	0.000	0.034	0.026	0.013	0.000	0.000	0.000	0.032	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.105
SS37 (15- 30)	0.04 6	0.000	0.000	0.038	0.030	0.015	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.083
SS38 (0- 15)	0.14 2	0.000	0.000	0.030	0.022	0.011	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.063
SS38 (15- 30)	0.25 6	0.000	0.000	0.015	0.007	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.021
SS39 (0- 15)	0.12 0	0.000	0.000	0.055	0.049	0.021	0.000	0.000	0.008	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.132
SS39 (15- 30)	0.06 7	0.000	0.000	0.031	0.023	0.011	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.066
SS40 (0- 15)	0.09 8	0.000	0.000	0.036	0.023	0.012	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.071
SS40 (15- 30)	0.03 2	0.000	0.000	0.027	0.016	0.008	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.051

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COM PON ENT	Alip hatic	Polycyclic Aromatic Hydrocarbons																
		Naph thale ne	Acen aphth alene	Acen aphth ene	Flore ne	Phen athre ne	Anthr acene	Fluor anthe ne	Pyren e	Benz o(a)a nthra cene	Cryse ne	Benz o(b)fl uoran threne	Benz o(a)p yrene	Benz o(k)fl uoran threne	Inden o(1,2 ,3) peryl ene	Dibe nzo(a ,h)ant hrace ne	Benz o(g,h ,i) peryl ene	Total PAH (mg/ kg)
SS41 (0- 15)	0.02 9	0.000	0.000	0.051	0.037	0.018	0.007	0.007	0.009	0.008	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.136
SS41 (15- 30)	0.02 9	0.000	0.000	0.045	0.029	0.013	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.087
SS42 (0- 15)	0.03 0	0.000	0.000	0.035	0.025	0.013	0.000	0.000	0.000	0.007	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.081
SS42 (15- 30)	0.02 0	0.000	0.000	0.063	0.045	0.019	0.000	0.000	0.000	0.012	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.139
SS43 (0- 15)	0.04 5	0.000	0.000	0.039	0.034	0.017	0.000	0.000	0.000	0.015	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.104
SS43 (15- 30)	0.05 1	0.000	0.000	0.037	0.029	0.013	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.079
SS44 (0- 15)	0.06 1	0.000	0.003	0.000	0.000	0.000	0.010	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.013
SS44 (15- 30)	0.03 6	0.000	0.020	0.000	0.000	0.000	0.030	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.050

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		Naph thale ne	Acen aphth alene	Acen aphth ene	Flore ne	Phen athre ne	Anthr acene	Fluor anthe ne	Pyren e	Benz o(a)a nthra cene	Cryse ne	Benz o(b)fl uoran threne	Benz o(a)p yrene	Benz o(k)fl uoran threne	Inden o(1,2 ,3) peryl ene	Dibe nzo(a ,h)ant hrace ne	Benz o(g,h, i) peryl ene	Total PAH (mg/ kg)
SS45 (0- 15)	0.02 1	0.000	0.004	0.000	0.000	0.000	0.008	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.012
SS45 (15- 30)	0.05 7	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	<0.00 1
SS46 (0- 15)	0.03 2	0.000	0.000	0.000	0.000	0.000	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002
SS46 (15- 30)	0.03 2	0.000	0.006	0.000	0.003	0.000	0.005	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.013
SS47 (0- 15)	0.00 6	0.000	0.003	0.000	0.000	0.000	0.007	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.010
SS47 (15- 30)	0.00 5	0.000	0.003	0.000	0.000	0.000	0.006	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.009
SS48 (0- 15)	0.00 3	0.000	0.000	0.000	0.000	0.000	0.011	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.011
SS48 (15- 30)	0.01 6	0.000	0.004	0.000	0.000	0.000	0.009	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.014

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		Naph thale ne	Acen aphth alene	Acen aphth ene	Flore ne	Phen athre ne	Anthr acene	Fluor anthe ne	Pyren e	Benz o(a)a nthra cene	Cryse ne	Benz o(b)fl uoran threne	Benz o(a)p yrene	Benz o(k)fl uoran threne	Inden o(1,2 ,3) peryl ene	Dibe nzo(a ,h)ant hrace ne	Benz o(g,h, i) peryl ene	Total PAH (mg/ kg)
SS49 (0- 15)	0.00 6	0.000	0.000	0.000	0.000	0.000	0.007	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.007
SS49 (15- 30)	0.00 4	0.000	0.003	0.000	0.000	0.000	0.007	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.010
SS50 (0- 15)	0.00 3	0.000	0.008	0.000	0.000	0.000	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.012
SS50 (15- 30)	0.01 0	0.000	0.002	0.000	0.000	0.000	0.017	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.019
SS51 (0- 15)	0.01 7	0.000	0.004	0.000	0.000	0.000	0.008	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.011
SS51 (15- 30)	0.00 3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	<0.00 1
SS52 (0- 15)	0.00 3	0.000	0.000	0.000	0.000	0.001	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002
SS52 (15- 30)	0.00 2	0.000	0.000	0.000	0.000	0.001	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.004

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COM PON ENT	Alip hatic	Polycyclic Aromatic Hydrocarbons																
		Naph thale ne	Acen aphth alene	Acen aphth ene	Flore ne	Phen athre ne	Anthr acene	Fluor anthe ne	Pyren e	Benz o(a)a nthra cene	Cryse ne	Benz o(b)fl uoran threne	Benz o(a)p yrene	Benz o(k)fl uoran threne	Inden o(1,2 ,3) peryl ene	Dibe nzo(a ,h)ant hrace ne	Benz o(g,h ,i) peryl ene	Total PAH (mg/ kg)
SS53 (0- 15)	0.00 2	0.000	0.000	0.000	0.000	0.002	0.002	0.000	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.007
SS53 (15- 30)	0.00 8	0.000	0.000	0.000	0.000	0.003	0.003	0.000	0.003	0.000	0.007	0.000	0.000	0.000	0.000	0.000	0.000	0.016
SS54 (0- 15)	0.00 5	0.000	0.000	0.000	0.000	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002
SS54 (15- 30)	0.00 4	0.000	0.000	0.000	0.000	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002
SS55 (0- 15)	0.00 2	0.000	0.000	0.000	0.002	0.003	0.003	0.000	0.003	0.000	0.006	0.000	0.000	0.000	0.000	0.000	0.000	0.017
SS55 (15- 30)	0.00 4	0.000	0.000	0.000	0.000	0.001	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.003
SS56 (0- 15)	0.01 1	0.000	0.000	0.000	0.002	0.004	0.004	0.002	0.002	0.000	0.061	0.000	0.000	0.000	0.000	0.000	0.000	0.063
SS56 (15- 30)	0.00 2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.019	0.000	0.000	0.000	0.000	0.000	0.000	0.019

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COM PON ENT	Alip hatic	Polycyclic Aromatic Hydrocarbons																
		Naph thale ne	Acen aphth alene	Acen aphth ene	Flore ne	Phen athre ne	Anthr acene	Fluor anthe ne	Pyren e	Benz o(a)a nthra cene	Cryse ne	Benz o(b)fl uoran threne	Benz o(a)p yrene	Benz o(k)fl uoran threne	Inden o(1,2 ,3) peryl ene	Dibe nzo(a ,h)ant hrace ne	Benz o(g,h ,i) peryl ene	Total PAH (mg/ kg)
SS57 (0- 15)	0.00 2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.077	0.000	0.000	0.000	0.000	0.000	0.000	0.078
SS57 (15- 30)	0.07 4	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.059	0.000	0.000	0.000	0.000	0.000	0.000	0.061
SS58 (0- 15)	0.07 3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.009	0.000	0.000	0.000	0.000	0.000	0.000	0.009
SS58 (15- 30)	0.08 2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.088	0.000	0.000	0.000	0.000	0.000	0.000	0.089
SS59 (0- 15)	0.12 3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.083	0.000	0.000	0.000	0.000	0.000	0.000	0.084
SS59 (15- 30)	0.01 2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.037	0.000	0.000	0.000	0.000	0.000	0.000	0.038
SS60 (0- 15)	0.11 6	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.041	0.000	0.000	0.000	0.000	0.000	0.000	0.042
SS60 (15- 30)	0.03 6	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	<0.01

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COM PON ENT	Alip hatic	Polycyclic Aromatic Hydrocarbons																
		Naph thale ne	Acen aphth alene	Acen aphth ene	Flore ne	Phen athre ne	Anthr acene	Fluor anthe ne	Pyren e	Benz o(a)a nthra cene	Cryse ne	Benz o(b)fl uoran threne	Benz o(a)p yrene	Benz o(k)fl uoran threne	Inden o(1,2 ,3) peryl ene	Dibe nzo(a ,h)ant hrace ne	Benz o(g,h, i) peryl ene	Total PAH (mg/ kg)
SS61 (0- 15)	0.01 8	0.000	0.000	0.062	0.068	0.033	0.005	0.000	0.000	0.009	0.000	0.000	0.002	0.000	0.000	0.000	0.000	0.179
SS61 (15- 30)	0.01 6	0.000	0.000	0.134	0.122	0.006	0.000	0.000	0.008	0.025	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.295
SS62 (0- 15)	0.13 3	0.000	0.000	0.046	0.030	0.041	0.000	0.000	0.010	0.030	0.000	0.000	0.026	0.017	0.000	0.000	0.000	0.035
SS62 (15- 30)	0.04 3	0.019	0.006	0.026	0.053	0.059	0.014	0.049	0.053	0.013	0.019	0.000	0.000	0.000	0.000	0.000	0.000	0.043
SS63 (0- 15)	0.03 4	0.000	0.000	0.004	0.005	0.037	0.000	0.000	0.010	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.058
SS63 (15- 30)	0.02 8	0.000	0.000	0.072	0.010	0.006	0.007	0.000	0.007	0.028	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.022
SSC1 (0- 15)	0.07 9	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	<0.00 1
SSC1 (15- 30)	0.04 0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	<0.00 1

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COM PON ENT	Alip hatic	Polycyclic Aromatic Hydrocarbons																	
		Naph thale ne	Acen aphth alene	Acen aphth ene	Flore ne	Phen athre ne	Anthr acene	Fluor anthe ne	Pyren e	Benz o(a)a nthra cene	Cryse ne	Benz o(b)fl uoran threne	Benz o(a)p yrene	Benz o(k)fl uoran threne	Inden o(1,2 ,3) peryl ene	Dibe nzo(a ,h)ant hrace ne	Benz o(g,h, i) peryl ene	Total PAH (mg/ kg)	
SSC2 (0- 15)	0.05 5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	<0.00 1
SSC2 (15- 30)	0.02 7	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	<0.00 1

Appendix 4.6.5.3 a Contd.:

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Hydrocarbons measurement in soils of the study area during wet season

COMPONENT	Benzene	Toluene	Ethylbenzene	m - Xylene	p - Xylene	o - Xylene	Total BTEX (mg/kg)
SS1 (0-15)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS1 (15-30)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS2 (0-15)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS2 (15-30)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS3 (0-15)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS3 (15-30)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS4 (0-15)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS4 (15-30)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS5 (0-15)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS5 (15-30)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS6 (0-15)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS6 (15-30)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS7 (0-15)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS7 (15-30)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS8 (0-15)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS8 (15-30)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS9 (0-15)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS9 (15-30)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS10 (0-15)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS10 (15-30)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS11 (0-15)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS11 (15-30)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS12 (0-15)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS12 (15-30)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001

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COMPONENT	Benzene	Toluene	Ethylbenzene	m - Xylene	p - Xylene	o - Xylene	Total BTEX (mg/kg)
SS13 (0-15)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS13 (15-30)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS14 (0-15)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS14 (15-30)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS15 (0-15)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS15 (15-30)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS16 (0-15)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS16 (15-30)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS17 (0-15)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS17 (15-30)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS18 (0-15)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS18 (15-30)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS19 (0-15)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001

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COMPONENT	Benzene	Toluene	Ethylbenzene	m - Xylene	p - Xylene	o - Xylene	Total BTEX (mg/kg)
SS19 (15-30)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS20 (0-15)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS20 (15-30)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS21 (0-15)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS21 (15-30)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS22 (0-15)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS22 (15-30)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS23 (0-15)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS23 (15-30)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS24 (0-15)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS24 (15-30)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS25 (0-15)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS25 (15-30)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001

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COMPONENT	Benzene	Toluene	Ethylbenzene	m - Xylene	p - Xylene	o - Xylene	Total BTEX (mg/kg)
SS26 (0-15)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS26 (15-30)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS27 (0-15)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS27 (15-30)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS28 (0-15)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS28 (15-30)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS29 (0-15)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS29 (15-30)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS30 (0-15)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS30 (15-30)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS31 (0-15)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS31 (15-30)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS32 (0-15)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001

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COMPONENT	Benzene	Toluene	Ethylbenzene	m - Xylene	p - Xylene	o - Xylene	Total BTEX (mg/kg)
SS32 (15-30)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS33 (0-15)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS33 (15-30)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS34 (0-15)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS34 (15-30)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS35 (0-15)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS35 (15-30)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS36 (0-15)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS36 (15-30)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS37 (0-15)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS37 (15-30)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS38 (0-15)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS38 (15-30)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001

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COMPONENT	Benzene	Toluene	Ethylbenzene	m - Xylene	p - Xylene	o - Xylene	Total BTEX (mg/kg)
SS39 (0-15)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS39 (15-30)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS40 (0-15)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS40 (15-30)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS41 (0-15)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS41 (15-30)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS42 (0-15)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS42 (15-30)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS43 (0-15)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS43 (15-30)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS44 (0-15)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS44 (15-30)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS45 (0-15)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001

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COMPONENT	Benzene	Toluene	Ethylbenzene	m - Xylene	p - Xylene	o - Xylene	Total BTEX (mg/kg)
SS45 (15-30)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS46 (0-15)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS46 (15-30)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS47 (0-15)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS47 (15-30)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS48 (0-15)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS48 (15-30)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS49 (0-15)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS49 (15-30)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS50 (0-15)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS50 (15-30)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS51 (0-15)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS51 (15-30)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001

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COMPONENT	Benzene	Toluene	Ethylbenzene	m - Xylene	p - Xylene	o - Xylene	Total BTEX (mg/kg)
SS52 (0-15)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS52 (15-30)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS53 (0-15)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS53 (15-30)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS54 (0-15)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS54 (15-30)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS55 (0-15)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS55 (15-30)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS56 (0-15)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS56 (15-30)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS57 (0-15)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS57 (15-30)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS58 (0-15)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001

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COMPONENT	Benzene	Toluene	Ethylbenzene	m - Xylene	p - Xylene	o - Xylene	Total BTEX (mg/kg)
SS58 (15-30)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS59 (0-15)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS59 (15-30)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS60 (0-15)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS60 (15-30)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS61 (0-15)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS61 (15-30)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS62 (0-15)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS62 (15-30)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS63 (0-15)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS63 (15-30)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SSC1 (0-15)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SSC1 (15-30)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001

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COMPONENT	Benzene	Toluene	Ethylbenzene	m - Xylene	p - Xylene	o - Xylene	Total BTEX (mg/kg)
SSC2 (0-15)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SSC2 (15-30)	0.000	0.000	0.000	0.000	0.000	0.000	<0.001

Appendix 4.6.5.3 b:

Hydrocarbons measurement in soils of the study area during dry season

COMPO NENT	Aliphatic	Polycyclic Aromatic Hydrocarbons																
	nC8 - nC44	Naphthal ene	Acen apht hale ne	Acen apht hene	Flor ene	Phen athr ene	Anth race ne	Fluo rant hene	Pyre ne	Benz o(a)a nthr acen e	Crys ene	Benz o(b)f luor anth rene	Benz o(a)p yren e	Benz o(k)f luor anth rene	Inde no(1, 2,3) peryl ene	Dibe nzo(a,h)a nthr acen e	Benz o(g,h ,i) peryl ene	Tota l PAH (mg/ kg)
SSC1 (0-15)cm	0.020	0.000	0.00 0	0.000	0.00 0	0.000	0.00 0	0.000	0.000	0.00 0	0.000	0.00 0	0.000	0.00 0	0.000	0.00 0	0.000	<0.0 01
SSC1 (15- 30cm)	0.019	0.000	0.00 0	0.000	0.00 0	0.000	0.00 0	0.000	0.000	0.00 0	0.000	0.00 0	0.000	0.00 0	0.000	0.00 0	0.000	<0.0 01
SSC2 (0-15)cm	0.028	0.000	0.00 2	0.001	0.00 0	0.007	0.00 0	0.000	0.000	0.00 0	0.004	0.00 0	0.000	0.00 0	0.000	0.00 0	0.000	0.014
SSC2 (15- 30)cm	0.027	0.000	0.00 8	0.005	0.00 0	0.000	0.00 0	0.000	0.005	0.00 0	0.005	0.00 0	0.000	0.00 0	0.000	0.00 0	0.000	0.022
SS5 (0-15)cm	0.028	0.000	0.00 6	0.000	0.00 0	0.003	0.00 0	0.000	0.007	0.00 9	0.006	0.00 0	0.000	0.00 0	0.000	0.00 0	0.000	0.030
SS5 (15- 30)cm	0.039	0.000	0.00 9	0.007	0.00 0	0.000	0.00 0	0.000	0.006	0.00 0	0.006	0.00 0	0.000	0.00 0	0.000	0.00 0	0.000	0.028
SS6 (0-15)cm	0.018	0.001	0.00 0	0.007	0.00 3	0.002	0.00 0	0.000	0.000	0.00 0	0.006	0.00 0	0.000	0.00 0	0.000	0.00 0	0.000	0.019
SS6 (15- 30)cm	0.013	0.001	0.00 0	0.000	0.00 1	0.001	0.00 0	0.000	0.000	0.00 0	0.003	0.00 0	0.000	0.00 0	0.000	0.00 0	0.000	0.006

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COMPO NENT	Aliphatic	Polycyclic Aromatic Hydrocarbons																
	nC8 - nC44	Naphthalene	Acenaphthalene	Acenaphthene	Fluorene	Phenanthrene	Anthracene	Fluoranthene	Pyrene	Benz(a)anthracene	Crysene	Benz(b)fluoranthene	Benz(a)pyrene	Benz(k)fluoranthene	Indeno(1,2,3)perylene	Dibenzo(a,h)anthracene	Benz(g,h,i)perylene	Total PAH (mg/kg)
SS7 (0-15) cm	0.024	0.000	0.000	0.000	0.001	0.001	0.000	0.000	0.000	0.000	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.005
SS7 (15-30) cm	0.014	0.001	0.000	0.000	0.001	0.001	0.000	0.000	0.000	0.000	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.008
SS8 (0-15) cm	0.039	0.001	0.000	0.000	0.001	0.001	0.000	0.000	0.000	0.000	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.007
SS8 (15-30) cm	0.037	0.000	0.000	0.000	0.001	0.001	0.001	0.001	0.000	0.000	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.007
SS9 (0-15) cm	0.038	0.001	0.000	0.000	0.001	0.001	0.000	0.000	0.000	0.000	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.007
SS9 (15-30) cm	0.005	0.000	0.000	0.007	0.001	0.003	0.000	0.000	0.000	0.002	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.017
SS10 (0-15) cm	0.006	0.001	0.000	0.000	0.002	0.002	0.000	0.000	0.000	0.000	0.005	0.000	0.000	0.000	0.000	0.000	0.000	0.009
SS10 (15-30) cm	0.007	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.003
SS11 (0-15)cm	0.015	0.001	0.000	0.000	0.001	0.001	0.000	0.000	0.000	0.000	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.005
SS11 (15-30) cm	0.021	0.001	0.000	0.000	0.001	0.001	0.000	0.000	0.000	0.000	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.007
SS12 (0-15) cm	0.006	0.001	0.000	0.000	0.001	0.001	0.000	0.000	0.000	0.000	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.007

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COMPO NENT	Aliphatic	Polycyclic Aromatic Hydrocarbons																
	nC8 - nC44	Naphthal ene	Acen apht hale ne	Acen apht hene	Flor ene	Phen athr ene	Anth race ne	Fluo rant hene	Pyre ne	Benz o(a)a nthr acen e	Crys ene	Benz o(b)f luor anth rene	Benz o(a)p yren e	Benz o(k)f luor anth rene	Inde no(1, 2,3) peryl ene	Dibe nzo(a,h) anthr acen e	Benz o(g,h ,i) peryl ene	Tota l PAH (mg/ kg)
SS12(15- 30) cm	0.014	0.001	0.00 0	0.004	0.00 1	0.001	0.00 0	0.000	0.000	0.00 0	0.000	0.00 0	0.000	0.00 0	0.000	0.00 0	0.000	0.007
SS13 (0- 15) cm	0.006	0.000	0.00 0	0.000	0.00 0	0.000	0.00 0	0.000	0.000	0.00 0	0.000	0.00 0	0.000	0.00 0	0.000	0.00 0	0.000	<0.0 01
SS13 (15-30) cm	0.010	0.000	0.00 0	0.000	0.00 0	0.000	0.00 0	0.000	0.000	0.00 0	0.000	0.00 0	0.000	0.00 0	0.000	0.00 0	0.000	<0.0 01
SS14 (0- 15) cm	0.009	0.000	0.00 0	0.000	0.00 0	0.000	0.00 0	0.000	0.000	0.00 0	0.000	0.00 0	0.000	0.00 0	0.000	0.00 0	0.000	<0.0 01
SS14(15- 30) cm	0.044	0.000	0.00 0	0.000	0.00 0	0.000	0.00 0	0.000	0.000	0.00 0	0.000	0.00 0	0.000	0.00 0	0.000	0.00 0	0.000	<0.0 01
SS15 (0- 15) cm	0.020	0.000	0.00 0	0.000	0.00 0	0.000	0.00 0	0.000	0.000	0.00 0	0.000	0.00 0	0.000	0.00 0	0.000	0.00 0	0.000	<0.0 01
SS15 (15-30) cm	0.022	0.000	0.00 0	0.000	0.00 0	0.000	0.00 0	0.000	0.000	0.00 0	0.000	0.00 0	0.000	0.00 0	0.000	0.00 0	0.000	<0.0 01
SS16 (0- 15) cm	0.005	0.009	0.00 8	0.002	0.00 7	0.000	0.00 0	0.000	0.000	0.00 0	0.000	0.00 0	0.000	0.00 0	0.000	0.00 0	0.000	0.025
SS16 (15-30) cm	0.006	0.001	0.00 3	0.002	0.00 2	0.001	0.00 0	0.000	0.000	0.00 0	0.000	0.00 0	0.000	0.00 0	0.000	0.00 0	0.000	0.009
SS17 (0- 15) cm	0.007	0.001	0.00 9	0.004	0.00 2	0.001	0.00 0	0.000	0.000	0.00 0	0.000	0.00 0	0.000	0.00 0	0.000	0.00 0	0.000	0.017
SS17 (15-30) cm	0.001	0.000	0.00 1	0.001	0.00 0	0.000	0.00 0	0.000	0.000	0.00 0	0.000	0.00 0	0.000	0.00 0	0.000	0.00 0	0.000	0.002

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COMPO NENT	Aliphatic	Polycyclic Aromatic Hydrocarbons																
	nC8 - nC44	Naphthalene	Acenaphthalene	Acenaphthene	Fluorene	Phenanthrene	Anthracene	Fluoranthene	Pyrene	Benz(a)anthracene	Crysene	Benz(b)fluoranthene	Benz(a)pyrene	Benz(k)fluoranthene	Indeno(1,2,3)perylene	Dibenzo(a,h)anthracene	Benz(g,h,i)perylene	Total PAH (mg/kg)
SS24(0-15) cm	0.004	0.000	0.004	0.006	0.004	0.003	0.010	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.031
SS24 (15-30) cm	0.008	0.008	0.008	0.004	0.004	0.001	0.002	0.006	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.037
SS27 (0-15) cm	0.001	0.008	0.000	0.003	0.006	0.003	0.007	0.010	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.042
SS27 (15-30) cm	0.006	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.008
SS28 (0-15) cm	0.001	0.007	0.001	0.002	0.000	0.000	0.000	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.018
SS28 (15-30) cm	0.002	0.000	0.001	0.006	0.000	0.000	0.000	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.014
SS29 (0-15) cm	0.002	0.003	0.000	0.001	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.012
SS29 (15-30) cm	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.008
SS30 (0-15) cm	0.002	0.003	0.003	0.001	0.002	0.005	0.005	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.024
SS30 (15-30) cm	0.004	0.003	0.002	0.002	0.003	0.003	0.005	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.023
SS31 (0-15) cm	0.006	0.004	0.003	0.002	0.008	0.004	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.028

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COMPO NENT	Aliphatic	Polycyclic Aromatic Hydrocarbons																
	nC8 - nC44	Naphthalene	Acenaphthalene	Acenaphthene	Fluorene	Phenanthrene	Anthracene	Fluoranthene	Pyrene	Benz(a)anthracene	Crysene	Benz(b)fluoranthene	Benz(a)pyrene	Benz(k)fluoranthene	Indeno(1,2,3)perylene	Dibenzo(a,h)anthracene	Benz(g,h,i)perylene	Total PAH (mg/kg)
SS31 (15-30) cm	0.004	0.000	0.000	0.009	0.002	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.017
SS32(0-15) cm	0.006	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS32 (15-30) cm	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS33 (0-15) cm	0.000	0.000	0.000	0.008	0.004	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.014
SS33 (15-30) cm	0.004	0.000	0.000	0.009	0.004	0.000	0.001	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.016
SS34 (0-15) cm	0.002	0.000	0.000	0.007	0.004	0.001	0.001	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.015
SS34 (15-30) cm	0.001	0.000	0.000	0.008	0.004	0.001	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.015
SS36 (0-15) cm	0.003	0.000	0.000	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.003
SS36 (15-30) cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001
SS37 (0-15) cm	0.000	0.000	0.000	0.005	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.006
SS37 (15-30) cm	0.000	0.000	0.000	0.006	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.007

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COMPO NENT	Aliphatic	Polycyclic Aromatic Hydrocarbons																
	nC8 - nC44	Naphthalene	Acenaphthalene	Acenaphthene	Fluorene	Phenanthrene	Anthracene	Fluoranthene	Pyrene	Benz(a)anthracene	Crysene	Benz(b)fluoranthene	Benz(a)pyrene	Benz(k)fluoranthene	Indeno(1,2,3)perylene	Dibenzo(a,h)anthracene	Benz(g,h,i)perylene	Total PAH (mg/kg)
SS38 (0-15) cm	0.000	0.000	0.000	0.005	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.010
SS38 (15-30) cm	0.000	0.000	0.000	0.000	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.005
SS39 (0-15) cm	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001
SS39 (15-30) cm	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001
SS40(0-15) cm	0.003	0.000	0.000	0.002	0.001	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.008
SS40 (15-30) cm	0.002	0.000	0.000	0.001	0.002	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.007
SS41(0-15) cm	0.003	0.000	0.000	0.001	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.005
SS41(15-30) cm	0.001	0.000	0.000	0.001	0.001	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.007
SS42 (0-15) cm	0.008	0.000	0.000	0.004	0.002	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.007
SS42 (15-30)cm	0.011	0.000	0.000	0.003	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.006
SS43 (0-15) cm	0.002	0.000	0.000	0.004	0.003	0.005	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.012

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COMPO NENT	Aliphatic	Polycyclic Aromatic Hydrocarbons																
	nC8 - nC44	Naphthalene	Acenaphthalene	Acenaphthene	Fluorene	Phenanthrene	Anthracene	Fluoranthene	Pyrene	Benz(a)anthracene	Crysene	Benz(b)fluoranthene	Benz(a)pyrene	Benz(k)fluoranthene	Indeno(1,2,3)perylene	Dibenzo(a,h)anthracene	Benz(g,h,i)perylene	Total PAH (mg/kg)
SS43 (15-30) cm	0.009	0.000	0.000	0.003	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.006
SS44 (0-15) cm	0.001	0.000	0.000	0.004	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.007
SS44 (15-30) cm	0.002	0.000	0.000	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.005
SS45 (0-15) cm	0.002	0.000	0.000	0.003	0.002	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.008
SS45 (15-30) cm	0.002	0.000	0.000	0.003	0.002	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.006
SS46 (0-15) cm	0.003	0.000	0.000	0.005	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.007
SS46 (15-30) cm	0.008	0.000	0.000	0.007	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.009
SS47 (0-15) cm	0.011	0.000	0.000	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.006
SS47 (15-30) cm	0.007	0.000	0.000	0.009	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.011
SS48 (0-15) cm	0.008	0.000	0.000	0.001	0.001	0.007	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.010
SS48 (15-30) cm	0.003	0.000	0.000	0.001	0.002	0.007	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.010

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COMPO NENT	Aliphatic	Polycyclic Aromatic Hydrocarbons																
	nC8 - nC44	Naphthalene	Acenaphthalene	Acenaphthene	Fluorene	Phenanthrene	Anthracene	Fluoranthene	Pyrene	Benz(a)anthracene	Crysene	Benz(b)fluoranthene	Benz(a)pyrene	Benz(k)fluoranthene	Indeno(1,2,3)perylene	Dibenzo(a,h)anthracene	Benz(g,h,i)perylene	Total PAH (mg/kg)
SS50 (0-15) cm	0.000	0.000	0.000	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.005
SS50 (15-30) cm	0.002	0.000	0.000	0.001	0.001	0.008	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.011
SS51 (0-15) cm	0.002	0.000	0.000	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.003
SS51(15-30) cm	0.005	0.000	0.000	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.003
SS53 (0-15) cm	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001
SS53 (15-30) cm	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001
SS56 (0-15) cm	0.009	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	<0.01
SS56 (15-30) cm	0.005	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	<0.01
SS57 (0-15) cm	0.008	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	<0.01
SS57 (15-30) cm	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	<0.01
SS58 (0-15) cm	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	<0.01

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COMPO NENT	Aliphatic	Polycyclic Aromatic Hydrocarbons																	
	nC8 - nC44	Naphthalene	Acenaphthalene	Acenaphthene	Fluorene	Phenanthrene	Anthracene	Fluoranthene	Pyrene	Benz(a)anthracene	Crysene	Benz(b)fluoranthene	Benz(a)pyrene	Benz(k)fluoranthene	Indeno(1,2,3)perylene	Dibenzo(a,h)anthracene	Benz(g,h,i)perylene	Total PAH (mg/kg)	
SS58 (15-30) cm	0.148	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS59 (0-15)cm	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS59 (15-30) cm	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS60 (0-15) cm	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS60 (15-30)cm	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS61 (0-15) cm	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS61 (15-30) cm	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS62 (0-15) cm	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS62 (15-30) cm	0.005	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	<0.001

Appendix 4.6.5.3 b Contd:

Hydrocarbons measurement in soils of the study area during dry season

COMPONENT	Benzene	Toluene	Ethylbenzene	m - Xylene	p - Xylene	o - Xylene	Total BTEX (mg/kg)
SSC1 (0-15)cm	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SSC1 (15-30)cm	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SSC2 (0-15)cm	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SSC2 (15-30)cm	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS5 (0-15)cm	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS5 (15-30)cm	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS6 (0-15)cm	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS6 (15-30)cm	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS7 (0-15) cm	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS7 (15-30) cm	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS8 (0-15) cm	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS8 (15-30) cm	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS9 (0-15) cm	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS9 (15-30) cm	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS10 (0-15) cm	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS10 (15-30) cm	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS11 (0-15)cm	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS11 (15-30) cm	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS12 (0-15) cm	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS12(15-30) cm	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS13 (0-15) cm	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS13 (15-30) cm	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS14 (0-15) cm	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS14(15-30) cm	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS15 (0-15) cm	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS15 (15-30) cm	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS16 (0-15) cm	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS16 (15-30) cm	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS17 (0-15) cm	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS17 (15-30) cm	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS24(0-15) cm	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS24 (15-30) cm	0.000	0.000	0.000	0.000	0.000	0.000	<0.001

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COMPONENT	Benzene	Toluene	Ethylbenzene	m - Xylene	p - Xylene	o - Xylene	Total BTEX (mg/kg)
SS27 (0-15) cm	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS27 (15-30) cm	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS28 (0-15) cm	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS28 (15-30) cm	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS29 (0-15) cm	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS29 (15-30) cm	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS30 (0-15) cm	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS30 (15-30) cm	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS31 (0-15) cm	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS31 (15-30) cm	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS32(0-15) cm	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS32 (15-30) cm	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS33 (0-15) cm	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS33 (15-30) cm	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS34 (0-15) cm	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS34 (15-30) cm	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS36 (0-15) cm	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS36 (15-30) cm	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS37 (0-15) cm	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS37 (15-30) cm	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS38 (0-15) cm	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS38 (15-30) cm	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS39 (0-15) cm	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS39 (15-30) cm	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS40(0-15) cm	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS40 (15-30) cm	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS41(0-15) cm	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS41(15-30) cm	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS42 (0-15) cm	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS42 (15-30)cm	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS43 (0-15) cm	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS43 (15-30) cm	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS44 (0-15) cm	0.000	0.000	0.000	0.000	0.000	0.000	<0.001

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COMPONENT	Benzene	Toluene	Ethylbenzene	m - Xylene	p - Xylene	o - Xylene	Total BTEX (mg/kg)
SS44 (15-30) cm	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS45 (0-15) cm	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS45 (15-30) cm	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS46 (0-15) cm	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS46 (15-30) cm	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS47 (0-15) cm	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS47 (15-30) cm	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS48 (0-15) cm	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS48 (15-30) cm	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS50 (0-15) cm	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS50 (15-30) cm	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS51 (0-15) cm	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS51(15-30) cm	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS53 (0-15) cm	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS53 (15-30) cm	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS56 (0-15) cm	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS56 (15-30) cm	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS57 (0-15) cm	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS57 (15-30) cm	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS58 (0-15) cm	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS58 (15-30) cm	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS59 (0-15)cm	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS59 (15-30) cm	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS60 (0-15) cm	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS60 (15-30)cm	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS61 (0-15) cm	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS61 (15-30) cm	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS62 (0-15) cm	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
SS62 (15-30) cm	0.000	0.000	0.000	0.000	0.000	0.000	<0.001

Appendix 4.6.5.4:

Microbiological measurement in soils of the study area

S/N	SAMPLE CODE	Wet season				Dry Season			
		(THB) X 104 (cfu/g)	(THF) X 103 (cfu/g)	(HUB) X 103 (cfu/g)	(HUF) X 102 (cfu/g)	(THB) X 104 (cfu/g)	(THF) X 103 (cfu/g)	(HUB) X 103 (cfu/g)	(HUF) X 102 (cfu/g)
1	SS1 (0-15)	1.30	0.35	0.62	0.20	1.58	0.42	0.15	0.04
2	SS1 (15-30)	1.80	0.35	0.62	0.20	1.68	1.26	0.82	0.09
3	SS2 (0-15)	1.20	0.25	0.60	0.07	2.15	1.47	0.88	0.19
4	SS2 (15-30)	2.40	0.30	0.22	0.03	1.34	0.72	0.71	0.13
5	SS3 (0-15)	1.70	0.06	0.30	0.02	1.82	1.65	0.87	0.08
6	SS3 (15-30)	5.20	0.45	0.42	0.02	1.69	0.95	0.37	NIL
7	SS4 (0-15)	4.30	0.05	0.35	0.03	4.39	0.77	0.58	0.09
8	SS4 (15-30)	6.20	0.75	0.01	NIL	3.98	1.83	0.24	0.03
9	SS5 (0-15)	5.80	0.04	0.40	0.03	4.46	1.13	0.25	0.03
10	SS5 (15-30)	3.50	0.06	0.59	0.07	3.85	0.90	0.97	0.02
11	SS6 (0-15)	4.30	0.05	0.65	0.05	4.68	1.14	0.21	0.05
12	SS6 (15-30)	2.60	0.03	0.70	0.03	1.99	0.89	0.45	0.06
13	SS7 (0-15)	5.70	0.25	0.10	0.03	4.09	0.78	0.12	0.08
14	SS7 (15-30)	1.90	0.02	0.49	0.02	1.78	1.04	0.29	0.05
15	SS8 (0-15)	4.40	0.05	0.33	0.02	4.72	1.22	0.22	0.02
16	SS8 (15-30)	1.10	0.15	0.3	0.03	4.24	2.31	0.42	0.13
17	SS9 (0-15)	3.80	0.05	0.42	0.02	2.88	1.37	0.23	0.04
18	SS9 (15-30)	5.60	0.05	0.40	0.05	3.90	1.19	0.92	0.17
19	SS10 (0-15)	1.00	0.50	0.35	0.08	3.91	0.80	0.83	0.06
20	SS10 (15-30)	5.40	0.04	0.50	0.02	3.97	0.70	0.96	0.05
21	SS11 (0-15)	6.50	0.48	0.37	0.05	2.68	0.27	0.12	0.02
22	SS11 (15-30)	7.00	0.55	0.67	0.03	3.03	1.18	0.56	0.04
23	SS12 (0-15)	4.20	0.07	0.53	0.02	4.92	1.12	0.19	0.15
24	SS12 (15-30)	5.90	0.09	0.33	0.04	2.75	0.95	0.52	NIL
25	SS13 (0-15)	7.60	0.05	0.47	0.05	1.74	0.99	0.66	0.04
26	SS13 (15-30)	7.10	0.08	0.49	0.08	5.94	1.14	0.83	0.08
27	SS14 (0-15)	3.20	0.35	0.45	0.04	5.47	0.32	0.18	0.09
28	SS14 (15-30)	2.10	0.62	0.72	0.15	2.12	0.18	0.98	0.11
29	SS15 (0-15)	5.80	0.10	0.50	0.05	3.10	1.28	0.53	0.08
30	SS15 (15-30)	1.70	0.1	0.11	NIL	1.78	0.42	0.44	NIL
31	SS16 (0-15)	4.40	0.03	0.45	0.02	2.83	0.64	0.26	NIL
32	SS16 (15-30)	7.80	0.02	0.60	0.04	6.80	0.98	0.38	0.06
33	SS17 (0-15)	5.40	0.08	0.37	0.05	2.81	0.78	0.91	0.06
34	SS17 (15-30)	1.30	0.20	0.69	0.09	3.07	0.52	0.72	0.06
35	SS18 (0-15)	2.50	0.40	0.27	0.05	2.88	0.95	0.97	0.08
36	SS18 (15-30)	6.30	2.40	0.52	NIL	2.99	1.64	0.57	NIL

S/N	SAMPLE CODE	Wet season				Dry Season			
		(THB) X 104 (cfu/g)	(THF) X 103 (cfu/g)	(HUB) X 103 (cfu/g)	(HUF) X 102 (cfu/g)	(THB) X 104 (cfu/g)	(THF) X 103 (cfu/g)	(HUB) X 103 (cfu/g)	(HUF) X 102 (cfu/g)
37	SS19 (0-15)	1.50	0.72	0.63	NIL	5.76	0.63	0.34	0.07
38	SS19 (15-30)	4.90	2.60	0.48	NIL	3.33	0.59	0.33	0.06
39	SS20 (0-15)	1.00	0.37	0.50	0.08	6.28	0.95	0.47	0.07
40	SS20 (15-30)	0.75	0.40	0.40	0.15	1.90	1.47	0.84	0.18
41	SS21 (0-15)	4.90	0.22	0.52	0.08	5.04	0.26	0.61	0.08
42	SS21 (15-30)	0.88	0.25	0.05	0.06	1.93	0.95	0.79	0.09
43	SS22 (0-15)	4.40	0.95	0.67	0.08	4.90	0.88	0.55	NIL
44	SS22 (15-30)	6.30	0.6	0.30	0.04	2.00	0.91	0.84	0.07
45	SS23 (0-15)	8.70	0.30	0.47	0.20	2.21	1.24	0.69	0.09
46	SS23 (15-30)	3.50	0.40	0.32	0.05	3.22	0.32	0.88	0.07
47	SS24 (0-15)	5.00	0.25	0.45	0.15	5.62	0.32	0.62	NIL
48	SS24 (15-30)	1.60	0.52	0.42	0.09	5.2`	0.22	0.94	0.08
49	SS25 (0-15)	6.30	0.63	0.19	0.04	3.60	0.54	0.58	0.05
50	SS25 (15-30)	8.30	0.46	0.24	0.05	3.76	0.28	0.75	0.09
51	SS26 (0-15)	0.35	0.10	0.35	0.03	4.86	0.75	0.53	0.07
52	SS26 (15-30)	5.60	0.53	0.32	0.04	4.40	0.89	0.81	NIL
53	SS27 (0-15)	7.20	0.29	0.20	0.06	2.19	0.36	0.67	NIL
54	SS27 (15-30)	0.92	0.52	0.37	0.08	3.80	0.32	0.86	NIL
55	SS28 (0-15)	0.55	0.84	0.56	NIL	1.35	0.38	0.61	0.08
56	SS28 (15-30)	1.00	0.46	0.15	NIL	1.17	1.62	0.92	0.08
57	SS29 (0-15)	5.70	0.47	0.42	0.04	4.70	0.78	0.51	0.06
58	SS29 (15-30)	0.87	0.02	0.51	0.02	2.28	0.77	0.65	0.08
59	SS30 (0-15)	7.80	0.73	0.43	NIL	1.71	0.23	0.47	0.06
60	SS30 (15-30)	9.00	0.08	0.61	0.05	1.27	0.64	0.45	0.05
61	SS31 (0-15)	5.70	0.45	0.32	NIL	3.76	0.87	0.44	0.08
62	SS31 (15-30)	6.60	0.42	0.53	0.05	2.72	0.53	0.20	0.04
63	SS32 (0-15)	7.40	0.74	0.20	NIL	4.18	0.62	0.21	0.09
64	SS32 (15-30)	1.40	0.67	0.50	0.05	4.32	0.88	0.75	0.07
65	SS33 (0-15)	2.00	0.53	0.17	NIL	5.22	0.56	0.71	0.07
66	SS33 (15-30)	0.25	0.54	0.47	NIL	2.55	0.98	0.95	0.08
67	SS34 (0-15)	3.80	0.23	0.12	NIL	3.78	0.74	0.23	0.12
68	SS34 (15-30)	5.60	0.05	0.48	0.05	1.76	0.63	0.63	NIL
69	SS35 (0-15)	0.57	0.75	0.60	0.05	4.94	2.21	0.60	0.08
70	SS35 (15-30)	2.30	1.83	0.40	0.03	4.66	0.29	0.73	0.09
71	SS36 (0-15)	7.40	1.41	0.30	0.08	2.51	0.75	0.42	0.07
72	SS36 (15-30)	0.37	0.47	0.37	0.08	3.81	0.97	0.84	0.11
73	SS37 (0-15)	0.46	0.10	0.93	0.07	4.18	0.34	0.20	0.06
74	SS37 (15-30)	6.40	0.80	0.35	0.05	2.92	0.31	0.12	0.04

S/N	SAMPLE CODE	Wet season				Dry Season			
		(THB) X 104 (cfu/g)	(THF) X 103 (cfu/g)	(HUB) X 103 (cfu/g)	(HUF) X 102 (cfu/g)	(THB) X 104 (cfu/g)	(THF) X 103 (cfu/g)	(HUB) X 103 (cfu/g)	(HUF) X 102 (cfu/g)
75	SS38 (0-15)	1.10	0.7	0.38	0.05	3.65	0.45	0.36	0.09
76	SS38 (15-30)	3.20	0.82	0.45	0.06	2.12	1.22	0.78	0.06
77	SS39 (0-15)	0.55	0.62	0.32	0.03	3.97	0.69	0.11	0.09
78	SS39 (15-30)	4.80	0.80	0.43	0.04	4.10	0.34	0.99	0.09
79	SS40 (0-15)	6.20	0.39	0.45	0.03	4.74	0.12	0.14	0.12
80	SS40 (15-30)	2.30	0.04	0.48	0.03	3.84	0.69	0.30	0.09
81	SS41 (0-15)	0.44	0.04	0.20	0.05	1.43	0.75	0.89	0.07
82	SS41 (15-30)	0.29	0.26	0.06	0.02	1.29	0.94	0.21	0.04
83	SS42 (0-15)	4.80	0.23	0.04	NIL	3.19	1.25	0.37	0.09
84	SS42 (15-30)	5.30	0.16	0.04	0.03	1.34	0.67	0.72	0.03
85	SS43 (0-15)	0.85	0.23	0.06	NIL	1.19	0.40	0.14	0.08
86	SS43 (15-30)	0.52	0.25	0.07	NIL	2.98	0.72	0.18	NIL
87	SS44 (0-15)	5.20	0.28	0.12	0.05	1.49	0.67	0.89	0.04
88	SS44 (15-30)	3.40	0.26	0.14	0.03	3.07	1.73	0.39	0.04
89	SS45 (0-15)	0.91	0.12	0.12	0.03	3.16	0.47	0.28	0.09
90	SS45 (15-30)	0.68	0.14	0.09	NIL	1.20	0.18	0.85	NIL
91	SS46 (0-15)	5.70	0.19	0.07	NIL	2.79	0.78	0.75	0.07
92	SS46 (15-30)	6.60	0.16	0.02	0.06	2.26	1.71	0.62	0.03
93	SS47 (0-15)	1.30	0.42	0.09	0.03	4.59	0.12	0.78	0.07
94	SS47 (15-30)	1.80	0.25	0.04	NIL	1.76	0.25	0.33	0.03
95	SS48 (0-15)	4.50	0.29	0.19	NIL	4.18	0.34	0.20	0.06
96	SS48 (15-30)	3.00	0.51	0.06	NIL	2.92	0.31	0.12	0.04
97	SS49 (0-15)	4.00	0.12	0.06	NIL				
98	SS49 (15-30)	4.50	0.70	0.07	0.06				
99	SS50 (0-15)	0.64	0.20	0.13	0.05	3.65	0.45	0.36	0.09
100	SS50 (15-30)	1.40	0.42	0.32	0.03	2.12	1.22	0.78	0.06
101	SS51 (0-15)	3.50	0.80	0.31	0.02	3.97	0.69	0.11	0.09
102	SS51 (15-30)	4.30	0.90	0.45	0.03	4.10	0.34	0.99	0.09
103	SS52 (0-15)	7.40	0.40	0.37	0.04				
104	SS52 (15-30)	5.90	0.20	0.77	0.02				
105	SS53 (0-15)	2.00	0.75	0.70	0.08	4.74	0.12	0.14	0.12
106	SS53 (15-30)	1.40	0.40	0.44	0.03	3.84	0.69	0.30	0.09
107	SS54 (0-15)	5.50	0.80	1.56	0.08				
108	SS54 (15-30)	3.20	0.90	0.93	0.05				
109	SS55 (0-15)	4.50	0.50	2.02	0.03				
110	SS55 (15-30)	2.00	0.60	2.88	0.09				
111	SS56 (0-15)	0.38	0.30	0.89	0.05	1.43	0.75	0.89	0.07
112	SS56 (15-30)	0.56	0.80	1.35	0.03	1.29	0.94	0.21	0.04

S/N	SAMPLE CODE	Wet season				Dry Season			
		(THB) X 104 (cfu/g)	(THF) X 103 (cfu/g)	(HUB) X 103 (cfu/g)	(HUF) X 102 (cfu/g)	(THB) X 104 (cfu/g)	(THF) X 103 (cfu/g)	(HUB) X 103 (cfu/g)	(HUF) X 102 (cfu/g)
113	SS57 (0-15)	6.00	0.30	1.16	0.04	3.19	1.25	0.37	0.09
114	SS57 (15-30)	4.30	0.80	0.95	0.07	1.34	0.67	0.72	0.03
115	SS58 (0-15)	6.20	0.50	2.08	0.02	1.19	0.40	0.14	0.08
116	SS58 (15-30)	5.00	0.34	0.10	0.03	2.98	0.72	0.18	NIL
117	SS59 (0-15)	0.61	0.36	0.80	0.03	1.49	0.67	0.89	0.04
118	SS59 (15-30)	0.73	0.41	0.88	0.02	3.07	1.73	0.39	0.04
119	SS60 (0-15)	4.70	0.38	0.63	0.03	3.16	0.47	0.28	0.09
120	SS60 (15-30)	3.80	1.57	0.30	0.09	1.20	0.18	0.85	NIL
121	SS61 (0-15)	3.90	0.50	0.50	0.08	2.79	0.78	0.75	0.07
122	SS61 (15-30)	1.30	1.70	0.55	0.27	2.26	1.71	0.62	0.03
123	SS62 (0-15)	1.50	1.00	0.42	NIL	4.59	0.12	0.78	0.07
124	SS62 (15-30)	0.42	0.40	0.90	NIL	1.76	0.25	0.33	0.03
125	SS63 (0-15)	1.90	1.12	0.50	0.02				
126	SS63 (15-30)	0.42	0.60	0.40	0.03				
127	SSC1 (0-15)	2.70	0.20	0.40	0.02				
128	SSC1 (15-30)	3.00	0.30	0.30	0.06				
129	SSC2 (0-15)	5.50	0.60	0.30	0.04				
130	SSC2 (15-30)	3.10	0.90	0.48	0.02				

Appendix 4.6.12.1:

Attendance sheet during Focus Group Discussion session with community representatives

~~31~~ 08-16 2nd

NAMES OF COMM. REPS

SNO	NAME & PHONE NUMBER	COMM
1.	Chief Lawson Otolob 08135627596 08086105823.	Obochi ✓
2	Chf. Philip J. Orowkwe 08170273580	Otoleto
3	Chf. Uka Chikwu 07050272073	Oleke *
4	Chf: Noman Otolob 08034960835	Obede.

~~307~~ 08-16

2nd

NAMES OF COMM. REPS

S/NO	NAME & PHONE NUMBER	COMM
1.	Chief Laurens Otolob 08135627596 08086105823.	Obodhi ✓
2	Chf. Philip J. Ovwakwe 08170273580	Ogbotogbo
3	Chife Uka Chikwura 07050272073	Odiere *
4	Chf. Norman Otolob 08034960835	Ogbede.

~~RIF~~ ~~FGD~~ of **EMUGHAN CLAN**
ENWHE

1ST

1. Stanley Harcourt SPDC
2. Okodudu Stephen SPDC
3. Emmanuel Dakah 08067983855 - OWEREWERE
4. AKEWAL SAMUEL EBEPH (JP) 0807406129 - ENYESU
5. Goodlife Jomo Ezen 08037436767
6. Chief Saturday J. Kodi 08078900549 - Aminigboko

Egunughan Community

S/NO	NAMES / PHONE NO	Community	
1	HRH Hon Rowland James Obenemaire III OF 07035921858	OBBOGOTO CLAN	3rd ✓
2	Com Jeremiah Henry 07014248495	AKIOSBOLOSHO	✓
3	MR. ECHIZENI J. MATTHEW 08063331204 (CDC)	IKODI - EUGENIA	
4	CH. ELIJAH H. AQUAN 08055584970	OKARKI	✓
5	CHIEF WITA TO EBEPH (PANA) ILULEK	KUNIVWA	
6	ANNAH MARTIN 07088717713	KUNIVWA	✓

Appendix 4.6.12.2: List of Communities around the Enwhe field

O → Enuoghan clan

S/N	Community	Local Government Area	State
1	Okarki * 1	Ahoada West	Rivers
2	Akpogbologo ✓ * 2 Akio ogbobo	Abua/Odual Ahoada West	Rivers
3	Ikode = Ikede	Abua/Odual Ahoada West	Rivers
4	Okparaki	Abua/Odual Ahoada West	Rivers
5	Ozorchi	Abua/Odual Ahoada East	Rivers
6	Ogbema	Ahoada West → Abua/Odual	Rivers
7	Abassu	Ahoada West	Rivers
8	Ochigwe origine	Abua/Odual Alameda West	Rivers
9	Amiri	Ahoada West	Rivers
10	Owerewere ①	Abua/Odual	Rivers
11	Aminigboko ②	Abua/Odual	Rivers
12	Agunughan ③	Abua/Odual	Rivers
13	Emesu ④	Abua/Odual	Rivers
14	Emebu ⑤	Abua/Odual	Rivers
15	Ogbogolo } Ogbogolo	Abua/Odual → Ahoada West	Rivers
16	Opu-Ogbogolo	Abua/Odual	Rivers
17	Kala-Ogbogolo	Abua/Odual	Rivers
18	Okabor ⑦	Abua/Odual	Rivers
19	Obrany ⑧	Abua/Odual	Rivers
20	Ovelemini	Abua/Odual	Rivers
21	Abessa	Abua/Odual = ?	Rivers
22	Okutukutu	Yenagoa	Bayelsa
23	Okolobiri	Yenagoa	Bayelsa
24	Obunagha	Yenagoa	Bayelsa
25	Agudama-Epie	Yenagoa	Bayelsa
26	Akenfa	Yenagoa	Bayelsa

Igbuduya Ulan (Ahoada West) Ekpe...

Ogbologbolo *
Obadbi ✓ ③*
Ogbode * *

Appendix 5a
Field work Attendance Sheet (Wet season)

SHELL PETROLEUM DEVELOPMENT COMPANY OF NIGERIA LIMITED
NLNG GAS SUPPLIES PROJECTS, GBARAN ENWHE

JOURNEY MANAGEMENT BRIEFING/TOOLBOX

LOCATION: MIZA CAMP SITE, GBARAN PHASE III EIA PROJECT DATE: 31/08/16

PRESENTER NAME: OLLEY JOHNSON

KEY MANAGEMENT BRIEFING TOPIC: SECURITY TIPS


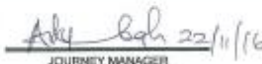

ATTENDANCE				
S/N	NAMES	JOB TITLE	DESTINATION	SIGNATURE
1	Orake Asemotona O	RPR	PDC	
2	Ngwuwa Hagar YILSU	FINANC - ENYA		
3	Andrea Chuedu - Adurobi	Enatal SPDC		
4	Morah Sunny	Michharry		
5	Mensah Joseph			
6	Boyal Ekwerekiwe	Muchharry		
7	BEST OJINIOHA	MICHARRY		
8	Oki Marbel	BSMENVIR		
9	Kare Oluoson	PSS		
10	Pius Nwobi	Scavenger/Guard	Abua	
11	Godwin Lida	Driver		
12	Katrick Njoku			
13	Onuriana John	MICHARRY DRG		
14	Isyem Lucky	michharry driver	HILARY	
15	Prosper Uwadunsa	Michharry	Worri	
16	OBISKO EMMANUEL			
17	Oyewole Seun	michharry	✓	
18	UDDKA IFEJIRA	✓	✓	
19	Kochiri Harry	Michharry	✓	
20	Vinuke Moses	SPDC	Smwke	
21	MONDAY AKPOTAYIRE	Muchharry	Driver	
22	OLLEY JOHNSON	SPDC	Lead (COO)	
23				

JOURNEY-MANAGER

HSE REPRESENTATIVE

**Appendix 5b
Field work Attendance Sheet (Dry season)**

1103

 THE SHELL PETROLEUM DEVELOPMENT COMPANY OF NIGERIA LIMITED GBARAN-UBIE INTEGRATED OIL AND GAS PROJECT				
JOURNEY MANAGEMENT BRIEFING / TOOLBOX RECORD				
TRACT NO	GBARAN-UBIE PROJECT	ENWHE	LOCATION: CPF SITE	DATE: 22/11/16
PRESENTER NAME: IJASAN OLERE				
KEY MANAGEMENT BRIEFING TOPIC: OLOMA STAND-DOWN				
ATTENDANCE				
S/N	NAMES	DESTINATION	JOB TITLE	SIGNATURE
1	Andee Chirachi Ajayi	Enwhe	Environment	[Signature]
2	IJASAN OLERE	ENWHE	Environment	[Signature]
3	MORAH SANWU	ENWHE	Hydrobiology	[Signature]
4	OTIYOLE, SERU	ENWHE	Hr quality	[Signature]
5	PROSPER UGADINISU	✓	bore hole	[Signature]
6	Atala Iyobu	✓	Geomatics	[Signature]
7	Godwin Ubal	Enwhe	HSE Officer	[Signature]
8	Munday Apotayin	Enwhe	Diner	[Signature]
9	Isitakhalo Harry	✓	Soil Consultant	[Signature]
10	Higazi Akubunmi	✓	Driver	[Signature]
11	Emanjibe George J.	✓	IT Support	[Signature]
12	OBILOK PRESTON	✓	Project	[Signature]
13	Amadi Ogozoba	ENWHE	Project	[Signature]
14	Okoro Mike	enwhe	Hydro Geology	[Signature]
15	Ngwoke Moses	enwhe	environmental	[Signature]
16	Bisoh Ekwerekwere	Enwhe	Electrical	[Signature]
17	Antan A. M.	Enwhe	Regulator	[Signature]
18	Maachukwu A	Ayalaokosofe	Log Co-ord	[Signature]
19				
20				
 JOURNEY MANAGER			 HSE REPRESENTATIVE	

