The Shell Petroleum Development Company of Nigeria Limited

ENVIRONMENTAL IMPACT ASSESSMENT STUDIES FOR THE JK EXPLORATION AND APPRAISAL WELLS PROJECT IN AKUKU TORU AND DEGEMA LOCAL GOVERNMENT AREAS OF RIVERS STATE AND BRASS LOCAL GOVERNMENT AREA OF BAYELSA STATE

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Table of Content

Status Page i
Table of Content ii
List of Tables vi
List of Figures viii
List of Plates xi
Abbreviations and Acronyms xii
Environmental Impact Assessment Preparers xiv
Executive Summary xv
CHAPTER ONE 1
INTRODUCTION 1
1.1: Background Information 1
1.2: EIA Objectives 1
1.3: Project Location 2
1.4: Legal and Administrative Framework 2
1.4.1: International Laws and Regulations 2
1.4.2: Legislations guiding Environmental management in Nigeria 4
1.4.3: Legislations guiding Environmental management in Rivers State 7
1.4.5: SPDC Policies and Principles 7
1.5: Declaration 9
1.6: Structure of the EIA 9
CHAPTER TWO 11
PROJECT JUSTIFICATION 11
2.1: Introduction 11
2.2: Need for Project 11
2.3: Benefit of the Project 11
2.4: Envisaged Sustainability 11
2.4.1: Economic sustainability 11
2.4.2: Technical Sustainability 12
2.4.3: Environmental Sustainability 12
2.5: Project options 12
2.6: Project Alternatives 13
2.7: Matrix Scoring Process 14
CHAPTER THREE 16
PROJECT AND PROCESS DESCRIPTION 16
3.1: Introduction 16
3.2: Project objectives 16
3.3: Project location 16
3.4: Project scope 17
3.5: Project activities 18
3.5.1: Premobilization phase 19
3.5.2: Mobilization 19
3.5.3: Drilling phase 19

3.6: Relationship with other nearby Projects 26
3.7: Decommissioning and Abandonment Plan 26
3.8: Waste Management Plan 27
3.9: Project schedule 33
CHAPTER FOUR 34
DESCRIPTION OF THE EXISTING ENVIRONMENT 34
4.1: General 34
4.2: Literature Review 34
4.3: Description of Sampling location 34
4.4: Sampling methodology 37
4.5: Quality Assurance and Quality control 37
4.6: Statistical Analyses 38
4.7: Meteorology and Air Quality 38
4.7.1: Climate and Meteorology 38
4.7.2: Air Quality and Noise 45
4.8: Water Quality Studies 47
4.9: Sediment quality 68
4.9: Hydrobiology 81
4.9.1: Phytoplankton Composition 81
4.9.2: Zooplankton composition of the JK Field 84
4.9.3: Macro Benthos composition of the JK Field 87
4.10: Fisheries Studies 93
4.11: Biodiversity Studies 103
4.11.1: Methodology 103
4.11.2: Reptilian Studies 107
4.11.3: Avifauna Studies 113
4.11.4: Mammalian Studies 117
4.12: Social Profile 120
4.12.1: Stakeholders Consultation 120
4.12.2: Population Dynamics and Sociocultural Characteristics 122
4.12.3: Population Size, Growth and Distribution 123
4.12.4: Marital Status 124
4.12.5: Distribution of respondents by age and sex 125
4.12.6: Distribution of Respondents by Household Headship 126
4.12.7: Distribution of Respondents by Educational Attainment 126
4.12.8: Distribution of Respondents by Household Size 129
4.12.9: Migration status in the Study Area 130
4.12.10: Pressure on Existing Infrastructure 131
4.12.11: Religious Affiliation in the study area 131
4.12.12: Culture and Tradition 133
4.12.13: Traditional Marriage 134
4.12.14: Political Structure and Governance 135
4.12.15: Conflict Management, Avoidance and Resolution Mechanisms 138

4.12.16: Social Control Mechanisms across the Communities..143
4.12.17: Natural Resources, Acquisition, Ownership and Management 144
4.12.18: Livelihood and Microeconomy...145
4.12.19: Income Distribution 147
4.12.20: Human and Economic Development Indices...149
4.12.21: Constraints to major productive activities in the study area....................................149
4.12.22: Employment status and distribution in the study area 150
4.12.23: Household consumption and Expenditure Pattern...150
4.12.24: Poverty profile in the study area 153
4.12.25: Infrastructural Facilities 155
4.12.26: Perceptions and expectations of the communities regarding the project (s)...........162
4.12.27: Anticipated Social problems and fears expressed by the communities. 163
4.13: Health Profile 164
4.13.1: Demographic characteristics of the communities 164
4.13.2: Birth Rates 164
4.13.3: Mortality Pattern..165
4.13.4: Healthcare Facilities and Services 166
4.13.5: Disease Pattern and Prevalence 166
4.13.6: Assessment of Blood Pressure of Adults 168
4.13.7: Women's Reproductive Health...169
4.13.8: Childhood Immunization 169
4.13.9: Nutritional Assessment and Household Food Security 169
4.13.10: Social and Lifestyle Issues Affecting Health...170
4.13.11: Environmental Health 170
4.13.12: Communities' Perception of the Proposed Project Benefits...................................173
CHAPTER FIVE 174
POTENTIAL AND ASSOCIATED ENVIRONMENTAL IMPACTS 174
5.1: Introduction...174
5.2: Uncertainties 174
5.3: Impact screening 175
5.4: Determination of project activities 175
5.5: Impact Qualification 179
5.6: Risk Assessment for Environmental Consequences...180
5.7: Impact Assessment Methodology 181
CHAPTER SIX 191
MITIGATION MEASURES 191
6.1: Introduction...191
6.2: Mitigation Measures 191
CHAPTER SEVEN 211
ENVIRONMENTAL MANAGEMENT PLAN...211
7.1: Introduction...211
7.2: SPDC's Corporate HSE Programme 211
7.3: Monitoring Objectives 212

7.4: Resourcing 212
7.5: Environmental Audits 212
7.6: Responsibilities and Training 212
7.7: Waste Management 213
7.8: Emergency Response Programme 213
7.9: Contractor Management 213
CHAPTER EIGHT 248
CONCLUSION 248
REFERENCES 249
APPENDICES 257

List of Tables

Table 2.1: Project Options considered 13
Table 2.2: Score description 14
Table 2.3: Surface location options ranking for the JK Exploration and Appraisal Wells Project 15
Table 3.1: The JK well inventory 18
Table 3.2: Well prospects and coordinates in the JK field 18
Table 3.3: Wells Casing Summary 20
Table 3.4: General Design Criteria for Wellhead Systems 22
Table 3.5: Drilling Fluid Selection for the JK Wells campaign 23
Table 3.6: Drilling Waste Types, Estimated Quantities and Corresponding Management Methods........ 29
Table 3.7: Operations Wastes Types, Estimated Quantities and Corresponding Management Methods........ 31
Table 4.1a: Quantities of samples to be obtained during the field data gathering 36
Table 4.1b: Sampling profiling along the JK field cluster 36
Table 4.1c: Summary of sample type and method of collection........ 37
Table 4.7.1: Summary of Results of Microclimatic data in the JK field area........ 44
Table 4.7.2: Summary of Results of Air Quality and Noise measurements in the JK field area 46
Table 4.8.1: Summary of surface water physicochemical and microbiological measurements in the JK field and control locations 50
Table 4.8.2: Summary of water column physicochemical and microbiological measurements in the JK field and control locations 61
Table 4.9.1: Summary of sediment physicochemical and microbiological measurements in the JK field and control locations 71
Table 4.9.1: Checklist of Phytoplankton in the JK Field. 81
Table 4.9.2: Ecological indices of the Phytoplankton in JK field during the present study 83
Table 4.9.3: Season variation of phytoplanktons in the JK field 84
Table 4.9.4: Checklist of Zooplankton in the JK Field 84
Table 4.9.5: Summary of Ecological indices of the Zooplankton in JK field during the present study 86
Table 4.9.6: Season variation of zooplanktons in the JK field 87
Table 4.9.7: Checklist of Benthic Fauna in the JK Field during the present study 87
Table 4.9.8: Summary of Ecological indices of the Benthic fauna in JK field during the present study 90
Table 4.9.9: Trending in Benthic fauna Community between 2018 and 2019 91
Table 4.10.1: Study Area Common Fish Species of Commercial Importance 96
Table 4.10.2: Fish species composition of fishermen catches in the area 98
Table 4.11.1: Turtle nesting sites and Soil sampling locations 105
Table 4.11.2: Locations of sightings of sea turtle species during the study 107
Table 4.11.3: Physicochemical Results of soils at nesting sites 111
Table 4.11.4: Check list of Censored Avian species and their specific traits 114

Table 4.11.5: Raptors of the Study Area 117
Table 4.11.6: Stakeholders Communities in Study Area 121
Table 4.12.7: Level of Educational Attainment in the Niger Delta States 127
Table 4.12.10: Deities mapped in some of the Project Communities 133
Table 4.12.12: Cultural Festivals in some of the Project Communities 133
Table 4.12.15: Trend of conflicts in Niger Delta (including selected communities of the proposed project) 139
Table 4.12.16: Inter-Community Conflicts in the Niger Delta Region 141
Table: 4.12.17: Intra-community conflicts in the area 142
Table 4.12.18: Conflict profile and resolution mechanisms across project communities 143
Table 4.12.19: Mapped Land Tenure System in the Study Area 144
Table 4.12.21: Constraints to Major Productive Activities 149
Table 4.12.23: Showing prices of commodities in the study area 151
Table 4.13.4: Commonly Used Medicinal Plants 166
Table 4.13.11: Sources of Domestic water in the communities 171
Table 5.1: Associated and Potential Impacts of the JK Exploration and Appraisal Wells Project 176
Table 5.2: Risk Assessment Matrix 180
Table 5.3: Further definition of consequence – severity rating for risk matrix 181
Table 5.4: Impact Value and Rating 183
Table 5.5: Ranking of Potential and Associated Impacts of the JK Exploration and Appraisal Wells Project 184
Table 6.1: Mitigation Measures for Significant Project Impacts 192
Table 7.1a: Environmental Management Plan for the JK Exploration and Appraisal Wells Project - Premobilization phase 215
Table 7.1b: Environmental Management Plan for the JK Exploration and Appraisal Wells Project - Mobilization phase 217
Table 7.1c: Environmental Management Plan for the JK Exploration and Appraisal Wells Project - Construction phase 219
Table 7.1d: Environmental Management Plan for the JK Exploration and Appraisal Wells Project - Drilling 226
Table 7.1e: Environmental Management Plan for the JK Exploration and Appraisal Wells Project - Demobilization 233
Table 7.1f: Environmental Management Plan for the JK Exploration and Appraisal Wells Project - Commissioning 237
Table 7.1g: Environmental Management Plan for the JK Exploration and Appraisal Wells Project - Operations and Maintenance 238
Table 7.1h: Environmental Management Plan for the JK Exploration and Appraisal Wells Project - Decommissioning and Abandonment 241
Table 7.2: Environmental Monitoring Plan for the JK Exploration and Appraisal Wells Project 245

List of Figures

Fig 1.1: Map of the Area of Interest of the JK field in OML 74 2
Fig 3.1: Map of the Area of Interest of the JK field in OML 74 16
Fig 3.2: JK Field and surrounding Prospects/Leads showing notional locations 17
Fig. 3.3: Producer Well architecture of the JK drilling campaign 21
Fig 3.4: Regional HB – HA – HM – HD – JK Stratigraphic Framework...............................26
Fig 3.5: Project Implementation Schedule 33
Fig 4.1: Sampling map for the JK Exploration and Appraisal Wells Project 35
Fig. 4.7.1: Mean Rainfall Distribution in the Study Area (NIMET, 2018) 39
Fig. 4.7.2: Mean Relative Humidity Distribution (NIMET, 2018) 39
Fig. 4.7.3: Mean Air Temperature Distribution (NIMET, 2018)..40
Fig. 4.7.4: Wind Speed and Prevailing Direction in the Study Area (NIMET, 2018) 40
Fig. 4.7.5: Mesured wind speeds in the project and control areas during the dry season........41
Fig. 4.7.6: Mesured wind speeds in the project and control areas during the wet season. 42
Fig. 4.7.7: Wind rose diagram for the JK field during the dry season. 42
Fig. 4.7.8: Wind rose diagram for the JK field during the wet season. 43
Figure 4.7.2: Measured levels of Nitrogen dioxide in the study area compared to National Limits. 45
Figure 4.8.1: Levels of pH in study area compared with control during the dry season 47
Figure 4.8.2: Levels of pH in study area compared with control during the wet season.........48
Figure 4.8.3: Electrical conductivity levels in the study area compared with control during the dry season...48
Figure 4.8.4: Electrical conductivity levels in the study area compared with control during the wet season 49
Figure 4.8.5: TSS levels in the study area compared with control during the dry season.......53
Figure 4.8.6: TSS levels in the study area compared with control during the wet season.......53
Figure 4.8.7: COD levels in the study area compared with control during the dry season 54
Figure 4.8.8: COD levels in the study area compared with control during the wet season.....55
Figure 4.8.9: Nutrient levels in the study area compared with control during the dry season.56
Figure 4.8.10: Nutrient levels in the study area compared with control during the wet season 57
Figure 4.8.11: Heavy metal levels in the study area compared with control during the dry season...58
Figure 4.8.12: Heavy metal levels in the study area compared with control during the wet season...59
Figure 4.8.13: Depth profile of water temperature in the study area compared with control during the dry season 60
Figure 4.8.14: Depth profile of water temperature in the study area compared with control during the wet season..60
Figure 4.8.15: Depth profile of electrical conductivity in the study area compared with control during the dry season...63
Figure 4.8.16: Depth profile of electrical conductivity in the study area compared with control during the wet season 63

Figure 4.8.17: Depth profile of DO in the study area compared with control during the dry season 64
Figure 4.8.18: Depth profile of DO in the study area compared with control during the wet season 64
Figure 4.8.19: Depth profile of nitrate in the study area compared with control during the wet season 65
Figure 4.8.20: Depth profile of nickel in the study area compared with control during the dry season 65
Figure 4.8.21: Depth profile of nickel in the study area compared with control during the wet season 66
Figure 4.8.22: Depth profile of iron in the study area compared with control during the dry season 66
Figure 4.8.23: Depth profile of iron in the study area compared with control during the wet season 67
Figure 4.8.24: Depth profile of lead in the study area compared with control during the dry season 67
Figure 4.8.25: Depth profile of lead in the study area compared with control during the wet season 68
Figure 4.9.1: Particle size distribution in the study area compared with control during the dry season 69
Figure 4.9.2: Particle size distribution in the study area compared with control during the wet season 69
Figure 4.9.3: Levels of pH in sediments of the study area compared with control during the dry season 70
Figure 4.9.4: Levels of pH in sediments of the study area compared with control during the wet season 70
Figure 4.8.5: Redox potential levels in sediments of the study area compared with control during the dry season 74
Figure 4.8.6: Redox potential levels in sediments of the study area compared with control during the wet season 74
Figure 4.8.7: TOC levels in sediments of the study area compared with control during the dry season 75
Figure 4.8.8: TOC levels in sediments of the study area compared with control during the wet season 75
Figure 4.8.9: Iron levels in sediments of the study area compared with control during the dry season 76
Figure 4.8.10: Iron levels in sediments of the study area compared with control during the wet season 77
Figure 4.8.11: Nickel and Zinc levels in sediments of the study area compared with control during the dry season 77
Figure 4.8.12: Nickel and Zinc levels in sediments of the study area compared with control during the wet season 78

Figure 4.8.13: Heavy metal levels in sediments of the study area compared with control during the dry season 79
Figure 4.8.14: Heavy metal levels in sediments of the study area compared with control during the wet season 80
Figure 4.9.1: Distribution of phytoplankton in JK field during present study 82
Figure 4.9.2: Distribution of Zooplankton in the JK field compared with control 85
Figure 4.9.3: Distribution of benthic fauna in the JK field compared with control 89
Fig. 4.11.1: Aerial imagery of Turtle nesting sites where soil samples were obtained 106
Fig. 4.11.2: Locations of sea turtle sightings during the study 108
Fig 4.11.3: Locations of mammalian sightings during the study 118
Figure 4.12.3: Fertility Rate in Nigeria, 2016 124
Figure 4.12.4: Marital Status 125
Figure 4.12.5a and b: Age distribution in the communities and Sex distribution in the communities 125
Figure 4.12.6: Distribution of Respondents by Household Headship 126
Figure 4.12.7: Educational Attainment / Literacy Status in the study communities 128
Figure 4.12.8: Educational Enrolment in the study area 128
Figure 4.12.9: Household size 129
Figure 4.12.10: Dependency Ratio in the Study Area 130
Figure 4.12.11: Migration Status in the study area 130
Figure 4.12.12: Respondents’ perception of level of pressure on existing infrastructure 131
Figure 4.12.13: Religious Affiliation in the study communities 132
Figure 4.12.14: Traditional/Political Governance structure @ the Clan level. 136
Figure 4.12.18: Changes in Livelihood Activities 147
Figure 4.12.19: Income distribution in the study communities 148
Figures 4.12.20: Engagement and years in Primary Activities. 148
Figure 4.12.22: Employment Status. 150
Figure 4.12.23: Household Consumption and Expenditure Pattern 151
Figures 4.12.24: Savings and Investment Patterns 152
Figure 4.12.25: Occupational Mobility and Adjustment of Labour 153
Figure 4.12.26: Poverty Status in the Study Area 154
Figure 4.12.27: Trend of Primary Occupation Source: Field survey 2018 155
Figures 4.12.29: Housing Type and ownership distribution in the study area. 156
Plates 4.12.30: Typical Housing structures in the study area 157
Figure 4.13.5a: Morbidity pattern of the children under 5 years 167
Figure 4.13.5b: 2019 Malaria Data in Brass and Degema LGAs 168
Figure 4.13.6: Prevalence of hypertension in the area 169
Figure 4.13.11: Sources of refuse disposal in the communities 171
Figure 4.13.12: Sources of sewage disposal in the communities 172
Fig. 5.1: Approach to Impact Assessment 179

List of Plates

Plate 3.1: Typical Jack up rig planned for the JK Wells drilling campaign 23
Well Clean-Up 24
Well Blow-out Analysis..25
Plate 4.10.1a: Benthic composition of the JK field 92
Plate 4.10.1b: Small fishing activity around the project area (a &b)......................................94
Plate 4.10.2: Species composition of catches from small-scale fishery in the project area.....99
Plate 4.10.3: *Sphyreana barracuda* (a), *Caranx* sp (b)and *Chaetodipterus goreensis* (c) caught around the project area 99
Plate 4.10.4: Some of the fishes caught by the small-scale fishermen around the project area 100
Plate 4.10.5: Fishing trawler operating around the project area 101
Plate 4.10.6: Fishes preserved in an improvised cold room by fishers around the project area 102
Plate 4.11.1: Biodiversity studies Crew, Hydroscope and underwater camera used for marine biodiversity studies 104
Plate 4.11.2: is the pictorial imagery of the delineated nesting sites 106
Plate 4.11.3: Representative avian taxa censored 114
Plate 4.11.4: Migratory Species of the study area 116
Plate 4.11.4: *Stenella frontalis* displaying behavioural signals 118
Plate 12.1.1: Engagement sessions with the communities..122
Plates 4.12.12: Predominant fishing festival and Dance in the study area 134
Plates 4.12.13: Scene and sites of traditional marriage ceremony in the study area 135
Plates 4.12.15: Symbols of Legendry Authority in Ijaw Kingdom 137
Plates 4.12.17: Some Water and Forest Resources in the Study area..................................145
Plates 4.12.18: Scenes of microeconomic activities in the study area and major occupation146
Plate 4.12.24: A typical market in the community 154
Plates 4.12.25: Typical Road infrastructure in the study area 155
Plate 4.12.31: Savings and investment mainly in fishing gears, transportation and property development..157
Plates 4.12.32: Typical means of transportation and communication in the study area........158
Plate 4.12.34: Typical Scenes in the study area...159
Plates 4.12.35: Educational Infrastructures and teaching/learning environment in the study area...159
Plates 4.12.36: Typical public water and sanitation facilities in the study area 160
Plates 4.12.37: Energy sources in the study area...161

Abbreviations and Acronyms

%	Percentage
BOD	Biochemical Oxygen Demand
C	Carbon
Ca	Calcium
$CaCO_3$	Calcium Carbonate
cfu	Colony forming unit
Cl	Chloride
cm	Centimeter
CO	Carbon monoxide
COD	Chemical Oxygen Demand
Cr	Chromium
Cu	Copper
dB	Decibel
DO	Dissolved Oxygen
DPR	Department of Petroleum Resources
EGASPIN	Environmental Guidelines and Standards for the Petroleum Industries in Nigeria
EIA	Environmental Impact Assessment
EMP	Environmental management plan
FGD	Focus Group Discussion
GMoU	Global Memorandum of Understanding
GPS	Global positioning system
H	Hydrogen
H_2O	Water
H_2S	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
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
NAOC	Nigeria Agip Oil Company
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
SCiN	Shell Companies in Nigeria
SO_4^{-2}	Sulphate ion
SPDC	Shell Petroleum Development Company
SPM	Suspended particulate Matter
STI	Sexually transmissible infections
TDS	Total Dissolved Solids
THB	Total heterotrophic bacteria
THC	Total hydrocarbon Content
TPH	Total Petroleum Hydrocarbon
VOC	Volatile Organic Compounds

Environmental Impact Assessment Preparers

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Executive Summary

ES 1.0: Introduction

The Shell Petroleum Development Company of Nigeria Limited (SPDC) on behalf of its Joint Venture Partners (Nigerian National Petroleum Corporation, Total Exploration and Production Nigeria and Nigerian Agip Oil Company) plans to appraise the discovered oil and gas resources and explore for new hydrocarbon resources (HC) in the JK field in OML 74 SPDC acreage. The exploration and appraisal drilling campaign is part of the Shallow Water Opportunities (SWO) development. The opportunity involves the drilling of 12 notional wells with average depth of penetration within ~ 10,000 to 13,000ft within an average water depth of 20 to 40m. The well discovered in-place volume of 201 MMSTB and 52 Bscf. This opportunity will boost the Federal Government and SPDC's oil and gas production targets, increase foreign exchange earnings and develop in-country capacity.

Following the potentials for interactions of the project activity with sensitive biological resources and environmental matrix within the project area, SPDC subjected this project to the DPR EIA process in line with the provisions of the Environmental Guidelines and Standards for Petroleum Industries in Nigeria (EGASPIN, 2018) and the FMEnv EIA procedural guidelines. The initial conceptual stages of the EIA have been completed with active participation of relevant stakeholders across Rivers State and regulators and approval of the Terms of Reference (ToR) and completion of a two season Field Data Gathering (FDG) exercise. 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 tailored mitigation measures to manage environmental risk to ALARP. The findings are hereby incorporated in this report.

ES 2.0: Project location

The JK Field is located in the western end of SPDC shallow offshore in OML 74 (J Block) and approximately 26km from Nigeria's coastline. Water depth around this concession is about 25 to 32 meters. The JK field is part of the H block (HB, HA, HD fields) macro structure with a regional northwest – southeast structural trend, offshore, Akuku Toru and Degema Local Government Areas of Rivers State, Nigeria and Brass Local Government Area of Bayelsa State.

ES 3.0: EIA Objectives

The objectives of the EIA are to:

- Acquire baseline data of the environment as well as the socio-economic and health conditions of the neighbouring coastal 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).

ES 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)
- Environmental Impact Assessment Act CAP E12 LFN 2004
- Endangered Species Act CAP E9 LFN 2004
- Petroleum Act CAP 350 LFN 1990
- International Union for Conservation of Nature and Natural Resources (IUCN) Guidelines, 2001
- Convention on Biological Diversity, 1992
- World Bank Guidelines on Environmental Assessment {EA} (1991)
- 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).
- Bayelsa State Environmental and Development Planning Authority Law 1998;
- Bayelsa State Pollution Compensation Tax Law 1998;
- Bayelsa State Forestry Law 1998.
- Bayelsa State Land Use (Environmental Degradation/Protection) Charge Law 2005.

ES 5.0: Need for Project

This exploration activity is to support JK-HD cluster development. The JK-3 discovery has appreciable resources with additional potential for the project to meet relevant portfolio screening criteria. The proposed JK exploration wells are expected to discover some of this volume and feed key development decisions including concept select for frontrunner oil scheduled for Q2 2021 and DG 3 in Dec 2021. Delivery of these wells is on the critical path, as DG3 acceleration on JK is strongly dependent on early availability of the exploration/appraisal drilling results.

ES 6.0: Benefit of the Project

The project will be executed under the legal structure of the existing SPDC joint venture with the Nigerian National Petroleum Corporation (NNPC). In a success case, these exploration wells will drive the development of the field with expected revenue from the sales of oil to be produced from the field. The financial proceeds will substantially increase the foreign exchange earnings of the Federal Government and help to improve the social and health standards of the neighbouring coastal communities around the OML74 area covered by the project. The exploration and appraisal drilling will also provide job opportunities for people around the neighbouring coastal communities.

ES 7.0: Envisaged Sustainability

Economic sustainability

The economic sustainability of the proposed field development in a success case exploration is high. The project will increase SPDC oil production and deliver cash to all the entities in the SPDC JV. The oil potential of the JK cluster can economically support the project increasing contribution to the revenue accruing to Nigeria and SPDC JV partners.

Technical Sustainability

The proposed project is technically viable as it will rely on existing and well-established technologies, with proven oil field experience and strong HSE awareness. The design and operation of the Wells would be carried out in line with national and international codes and standards of practice. Innovative technologies that are economically viable and having minimal environmental, social and health impacts shall be utilized in the execution of the proposed project. In addition, personnel with experience in similar operations will be involved in the transition and early operations.

Environmental Sustainability

The findings and recommendations of this EIA would be integrated into all phases of the proposed project lifecycle. Recommendations on the project process, waste management (handling, treatment and disposal) which were developed in line with the environmental regulations, guidelines and standards of the Federal Ministry of Environment and Department of Petroleum Resources as well as international best practices would ensure the environmental sustainability of the proposed project.

ES 8.0: Project options

(a) *No Project Option*

Advantages

- No capital expenditure
- No new risks
- No impact on the environment

Disadvantages

Major loss of potential revenue and opportunities for Nigeria by locking in hydrocarbon resource and stalling human/infrastructure development opportunities.

Remark: Not Recommended

(b)*Delayed Project Option*

Advantage

More time to plan and assess risks

Disadvantages

- Delay in achieving First Oil/Gas Date
- Loss of expected revenue for that period of time to Government and SPDC.

Remark: Not Recommended

©Drill Wells

Advantage

- Increase revenue to the government and SPDC
- Strong developmental pull to the JK field;
- Explore the identified Deep HC opportunities.
- Improve economy of coastal communities.

Disadvantage

- Increase in the Environmental footprint in the JK field.
- High Capital Expenditure
- Increased pressure on existing socio-economic activities in the field

Remark: Recommended

ES 9.0: Project objectives

The objective of the JK Cluster Exploratory and Appraisal Wells Project includes:

- Explore the identified HC opportunities around the JK field
- Appraising the discovered HC resource in the JK field.
- Supports the Federal Government and SPDC's oil and gas production targets.
- Monetizing the newly renewed blocks.

ES 10.0: Project scope

The scope of the JK Exploration and Appraisal Wells Project is to:

- Test the fault block south of the JK-3 drilled block for commercial quantities of hydrocarbons, gathering data for field appraisal and development. The primary targets are D7000, D9000, E1000, E3000, F1000.
- To support JK-HD cluster development. The JK-3 discovery has 2C resources of approximately 100 Mmbbl UR, with an estimated additional 70 MMbbl oil UR required for the project to meet screening criteria (Post FID VIR >0.5). The proposed JK-P exploration well is expected to discover some of this volume and feed key development decisions: "Concept Select for frontrunner oil" in Q2 2021 and DG 3 in Dec 2021. Delivery of these wells is on the critical path, as DG3 acceleration on JK is strongly dependent on early availability of the exploration/appraisal drilling results
- If successful, the well would be safely suspended. This would be followed by completion and hook-up as specified in the notional development plan. The JK campaign will involve the following:
- Drilling 12 Exploratory/Appraisal wells with a Jack-up rig in shallow waters of between 20m and 40 water depths in OML 74 of SPDC acreage.
- Planned to drill, plug back and suspend the exploration / appraisal wells.
- Some of the appraisal wells may be optimized for development/producer wells in the project life cycle and may be side-tracked.

ES 11.0: Project activities
The specific major activities of the proposed project to be carried out include

- Premobilization
- Mobilization
- Drilling;
- Waste management.
- Demobilization;
- Maintenance of well-head; and
- Decommissioning and abandonment.

ES 12.0: Waste Management
The bulk of waste generated will be from logistics, drilling operations, and decommissioning activities. The anticipated wastes from these activities include domestic wastes (e.g. food and trash), sanitary wastes, spent drill cuttings, used drilling muds, grey water, noxious gases and oily waters.

ES 13.0: Project schedule
Execution window for the JK Drilling campaign and maturation of Wells is planned for Q2, 2020.

ES 14.0: Description of the Existing environment
The baseline data acquisition is aimed at establishing the status of the components of the proposed project environment that are likely to be affected by the project. A multi-disciplinary approach was adopted for data acquisition and environmental characterization. Areas covered included climate, air quality and noise, surface water and sediment quality, hydrobiology and fisheries as well as marine biodiversity. Data was also obtained on the socioeconomic and health profiles of the communities within the proposed project zone of influence. 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 in accordance with the approved Terms of Reference and Scope of work.

Description of Sampling location
The JK Exploration and Appraisal Wells project EIA involved a two season field data gathering exercise conducted from 27th November 2018 through 7th December, 2018 (Dry season) and 8th through 17th September, 2019 (Wet season). The sampling rationale followed detailed protocol for offshore seabed sampling in accordance to international best practices, DPR and FMEnv guidelines. Details of sampling protocols were as follows:

- Air quality and noise measurements were sampled 200m away from the emission sources of the Well locations in the cardinal directions. Controls established outside the project area in the Windward (Upwind) and Downwind (Leeward) directions from the emission sources.

- Surface water and Sediment quality: Sampling was conducted in centric circles in the north, south, east and West direction at 200m, 500m, 800m, 1,200m from the proposed Well locations along the direction of most persistent bottom current.
- Control samples points located outside the JK field boundaries in the North, East and West locations to take cognisance of the dominant coastal hydrodynamics (tidal and longshore currents).

The summary of sampling points for various environmental spheres are as follows:

1.	Ambient Air quality and Noise	24 points + 3 Controls
2.	Surface Water Quality	72 points + 3 Controls
3.	Sediment Quality	96 points + 3 Controls;
4.	Social and Health Profile	12 communities

Quality Assurance/Quality Control

Strict adherence to best practice was observed in the QA/QC with regards to sample collection, *in situ* and laboratory analysis. Samples vessels were washed with detergent and rinsed thoroughly. Prior to sample collection. The vessels were rinsed again with the water to be sampled before sampling for analysis. All samples for laboratory analyses were accompanied with comprehensive chain of custody. All samples were analysed at International Energy Service Reference Laboratory in Port Harcourt, Rivers State. Other aspects of the QA/QC included the requirement that:

- Field and Laboratory routines be carried out by certified and experienced personnel only
- All analytical equipment be pre-calibrated in line with manufacturers requirements before use
- All samples be properly and securely labelled using indelible markers
- Only analytical grade reagents (Analar grade) and chemicals be used.

Climate and Meteorology

The JK field is located within the Gulf of Guinea and its climate is largely influenced by the Atlantic Ocean with dry and wet seasons associated with the movement of the Inter-Tropical Convergence Zone. Mean annual rainfall is about 3000 mm with South westerly/Southerly winds dominating at generally low speeds of 0.3 to 5 m/s. Other meteorological parameters including ambient temperature (27-33^{o}C), Relative humidity (50-80%), atmospheric pressure (1010-1014 mB) are normal for the study area.

Air Quality and Noise

All Air quality parameters were in compliance with National Regulatory limits. Sulphur dioxide, Carbon monoxide, Hydrogen sulphide, Volatile hydrocarbons, Ammonia and Ozone were not detected in the air shed. Nitrogen dioxide (0-9.9 µg/m^3) was detected only during the dry season within the project area with highest levels at ASW6 (Block D) and ASW11 (Block G). Suspended particulate matter (19-50 µg/m^3) had significantly higher values in the dry than wet season but was not different from control.

Surface water Quality

Measured quality parameters including, water temperature (26.1-32^{o}C), pH (8.07-8.65), EC (27150-47000 µS/cm), TSS (10-36 mg/l), DO (3.4-6.2 mg/l), BOD 0.1-3.4 mg/l), COD (149-205 mg/l), Nitrate (0.2-3.4 mg/l), Nickel (0.012-1.1 mg/l), Iron (0.014-0.437 mg/l), Lead (0.004-0.153 mg/l) and Zinc (0.001-0.234 mg/l) were within normal levels for the study area. Total alkalinity (8-33 mg/l) was assessed as being low while Phosphate (0.11-2.9 mg/l), was assessed as being high for normal coastal ocean water. Hydrocarbons including TPH, PAH and BTEX were not detected. Coliforms (max 4 MPN/100 ml) and bacteria and fungi (max 10^2 cfu/ml) were very low indicating unpolluted water.

Water column Water Quality

Significant depth trends were observed in water quality parameters including water temperature, electrical conductivity, dissolved oxygen and total suspended solids. The trends were characterized by decrease with depth in temperature and DO and increase with depth in EC and TSS which are normal for ocean waters. Hydrocarbons were not detected at all depths but a number of heavy metals including nickel showed depth trends characterized by increase with depth which is also considered normal in ocean waters. Concentrations at depths were all within normal levels for unpolluted ocean waters.

Sediment Quality

The sediment was generally muddy, being dominated by silt and clay. Routine Physicochemical quality parameters including sediment temperatures (15.1-21.5oC), pH (6.98-8.19), redox (-69.8-39.7 mV), TOC (0.18-3.81%) were normal for unpolluted ocean sediments. Exchangeable cations including sodium (1215-13952 mg/kg), potassium (513-757 mg/kg), magnesium (1986-2993 mg/kg) and calcium (609-1526 mg/kg) were normal for unpolluted ocean sediments and are considered adequate to provide necessary buffering against acidic condition. Heavy metals were generally low and within normal levels for unpolluted sediments. Nickel (1.028-322.1 mg/kg) was in exceedance of national and global limits for sediments at many locations but there was no significant difference between study locations and control showing its widespread nature in the area. Similarly, Cadmium values (0.238-13.258 mg/kg) were in exceedance of historical levels in the area and also exceeded the national and global limits including the DPR intervention limit of 12 mg/kg. Values of cadmium were significantly higher at proposed project locations than control a possible indication of localized sources of input.

PAH and BTEX were not detected in the sediments showing the absence of fresh or chronic pollution in the area. TPH (0.03-11 mg/kg) were low compared to minimum levels of concern in the ocean (>15 mg/kg) and DPR's target limit of 50 mg/kg.

Bacteria and fungi were very low (within 10^1 cfu/g while hydrocarbon utilizing microbes were undetected compared to normal values of 10^9 cfu/g for sediments, indicating absence of organic pollution.

Marine Ecology

Phytoplankton

Phytoplankton of JK field was composed of 24 species distributed in 17 families, 9 orders and 2 classes namely Bacillariophyceae (23 species, 94.73%) and Dinophyceae (1 species, 5.26%). Control location had more classes, namely Bacillariophyceae, Dinophyceae, Fragillariophyceae and Haptophyceae. Bacillariophyceae was the most abundant and dominant in both the study area and control. Shannon Wiener Diversity index ranged from 1.65-2.195 which translates to a stressed environment with poor to moderate water quality.

Zooplankton

Zooplankton of JK field was represented by 21 species belonging to 10 orders and 7 classes with the order of dominance being Hexanauplia (12 species, 60.74%)> Oligotrichea (4 species, 10.77%)> Malacostraca (3 species, 7.74%)> Stenolaemata, Polycheata, Branchiopoda and Calanoida (all having 1 species each). For the control, the order of dominace was Hexanauplia (6 species,69.66%)> Oligotrichea (4 species, 19.10%)> Stenolaemata (1 species,11.24%). Polycheata, Malacostraca, Branchiopoda and Calanoida were absent in the control points. Shannon Wiener Diversity ranged from 1.01-2.717 indicating a stressed environment with poor to moderate water quality.

Macrobenthic Fauna

Macrobenthic fauna was composed of 26 species distributed in 16 families, 10 orders and 2 classes namely Bivalvia (4 species, 92.25%) and Gastropoda (21 species, 7.48%). The bivalves showed a higher abundance than gastropods at all locations. The Shannon Wiener Diversity index for Macrobenthos ranged from 0-2.327 indicating a stressed environment with poor to moderate sediment quality.

Fisheries

The project area is dominated by artisanal fishers who either operate within the rivers, creeks and creeklets that open to the ocean using wooden canoes or in the near coast shallow ocean area using motorised wooden boats. The fishing gears are a mix of setlines, circling nets and seine nets as well as traps used mainly by women fishers. The fish is composed of a number of commercial trawl species such as Lutjanidae, Sparidae, Serranidae Cynoglossidae, Ariidae, Pomadasyidae, Haemulidae, Polynemidae, and Rajidae and artisanal species such as croakers (*Pseudotolithus*), threadfins (*Galeoides, Pentanemus* and *Polydactylus*), soles (Cynoglossidae), marine catfish (*Arius*), brackish water catfish (*Chrysichthys*), snapper (*Lutjanus*), grunts (Pomadasyidae), groupers (*Epinephelus*), and the estuarine white shrimp (*Palaemon*). Bonga dominates the pelagic fishery but there are modest catches of shad (*Ilisha*), sardine (*Sardinella*), various jacks (*Caranx spp*.) and Atlantic bumper (*Chloroscombrus chrysurus*). Fish migration is reported for some of the exploited fish species, e.g., bonga, croakers, sardinella, snappers, threadfins, pink shrimp and barracuda which make seasonal migrations from the sea into the creeks and back to mainly for the purpose of reproduction

Biodiversity

Reports of marine biodiversity distribution in the area indicate the presence of 7 mammals, 13 birds and 3 reptile species. Two mammalian, two reptilian and 18 avian species were actually sighted during the study while 3 mammalian and 3 reptilian taxa were censored via indirect evidence.

Reptiles

A total of 15 individuals of turtle were sighted, 9 of which belonged to Chelona mydas and 6 to Lepidochelys olivacea. Indirect evidence showed the potential presence of Dermochelys coriacea (Leatherback turtle) and Caretta caretta (Loggerhea turtle) as well as Crocodylus niloticus (Nile crocodile). All turtle sightings were within 400 m from shoreline at water depths of 3 to 9 m. The species are poached for eggs and meat in the project area as well as for traditional medicine while the shells find uses as ornaments for masquerades. Eggs and hatchlings are also preyed upon by land mammals, reptiles and crabs. With regards to conservation, Chelona mydas is categorized as endangered while Lepidochelys olivacea is vulnerable. Recommended management plan include delineation and access restriction to identified nesting sites, construction of egg chambers and capacity training for the active NGO in the area, the ADF.

Birds

A total of 61 individuals belonging to 18 avian species were censored during the study including *Nycticorax nycticorax*, *Casmerodius albus* and *Phalaropus fulicarius* which together accounted for 40% of the individuals censored. The most frequently sighted birds were *Nycticorax nycticorax, Casmerodius albus, Ardea cinerea, Anastomus lamelligerus, Bubulcus ibis, Hydroprogne caspia , Phalaropus fulicarius*. The migratory species included *Ardea cinereal, Anas crecca* and *ardenna grisea.* Among the avian species, a total of 9 raptor species, belonging to Ardeidae , Podicipedidae , Scolopacidae and Ciconiidae families were sighted and included *Ardea cinerea, Ardea Herodias, Nycticorax nycticorax, Botaurus stellaris, Tachybaptus ruficollis, Ardea goliath, Anastomus lamelligrus* and *Calidris alba*. No species of conservation concern were sighted in the area.

Mammals

A total of 4 mammalian species including *Orcinus orca* and *Stenella frontalis* (actually sighted) and *Trichechus senegalensis* and *Stenella longirostris* (inventoried through indirect evidence) were censored in the area. *Orcinus arca* were sighted at a water depth f 12-15m while *Stenella frontalis* was sighted at 7 m depth. All sighted individuals were travelling possibly in search of mating partners or away from unfavourable conditions. Both species are hunted by locals for meat and oil. Orcinus orca are at the top of the marine food chain and so have no natural predators while *Stenella frontalis* is hunted by large whales. Juveniles are vulnerable to being caught in fisher nets. The species are considered as data deficient and may be considered as threatened but they may be quite abundant and widespread in the area.

Socioeconomic Profile

Stakeholder communities, Governance, Customs and Religious beliefs

The stakeholder communities include Odioma, Ibidi, Obioku, Twon-Brass, Okpoama and Diema (Brass LGA, Bayelsa State); Kula, Abissa and their settlements all in Akuku-Toru Local Government Area of Rivers State as well as Elem-Oproama (Opu-Okolo, Abaji-Okolo, Gold Coast, Okolo-Ogono, Otama, Ngeribarama, and Bokokiri), College Kiri (Francis Okpoama), Amakiri Konboko (Old Sangama) and Elem-Ifoko communities in Degema Local Government Area of Rivers State of Nigeria. The traditional governance system is structured into hierarchies with about five (5) functional organs namely – the Amanyanabo (but now, College-kiri has a Regent) who is the paramount king or chief; Clan Heads, Village Heads, Executive Council and Youth Executive Council. Other important structures of administration include Women Associations, Community Development Committees and several Community and faith-based organizations. There is strong relationship and synergy between traditional (informal) leadership and the modern (formal) governance institutions in the study area.

Although the majority are Christians, other religions including Islam and traditional worship also exist in the area. For the Ijaw ancestral stock, it is crucial to hold in reverence the reminiscence of ancestors and religious traditions. Cultural practices include festivals and masquerade dances marked with feasting and merry making. There are a few sacrifices and general reverence for traditions and festivals associated with traditional worship. The communities have common cultural prohibitions which include killing and eating of snakes (python), sheep and eagles. The communities do not eat mutton or allow sheep or mutton to be brought into the community.

Land Ownership and Land Use

Land use is categorized under agricultural and non-agricultural use of land. Land in the area are classified as being individually-owned, family owned, community-owned and government-owned and land acquisition is mainly through inheritance, purchases, lease, pledge, exchange and gift. Traditionally, children inherit their fathers' properties. Usually, the first son and other sons have a prominence in family inheritances. Land in the area is used mainly for farming. Other indigenous uses of land include hunting, lumbering, harvesting of non-timber forest products, as well as housing and industry. Some forest and rivers are sacred sites with restricted access and are under the control of community chief priests.

Population and demography

Using an annual growth rate of 3.2%, the estimated population of the study area is put at 128,594 by 2020. Over 75% of the population are married with over 51% of the households aged 18-21 years which shows a dominantly young population. About 57% are females while 43% are males. Rapid increase in population of the communities was linked to increased economic activities in the project area. In some of the communities, the rate of immigration is as high as 60%. This has exerted pressure and competition on infrastructural facilities (such as housing, education and health, roads and electricity, etc), and land among others.

Population pattern in Akuku-Toru and Degema LGAs shows high population density in the urbanized upland areas such as Abonema, Buguma, and Bakana; there are no major urban centres in the coastal areas of interest, although Kula is evolving due to plans by Belema Oil to set up oil terminal operations there. Population in the coastal areas are largely concentrated in the main coastal communities such as Kula, Elem-Oproama, Elem-Ifoko etc. with dispersed population in the other settlements. Due to the dominant fisheries livelihood in these areas, there is seasonal population changes due to influx of fishermen to the settlements in the fishing season and emigration from the settlements back to the main communities in the ‘rough’ season usually during the rains.

Educational Attainment

Adult literacy in the study communities was above 60% with over 80% of the population haven completed either primary, secondary or tertiary education. Over 40% of the community attended and completed secondary education across the communities, 35% attended and completed primary education, 20% attended vocation/technical as well as colleges of education and polytechnics while 5% attended and completed university education showing a highly literate community.

Livelihood and Microeconomy

Over 60% of the population in the region depends on natural resources in the environment for their livelihood. Fishing, farming and trading are the major occupation of the people in the study area. Over 65% of the respondents are into fishing value chain which include harvesting, drying and marketing. About 20% and 10% are into farming and trading respectively while 5% are engaged in civil service, industry and other forms of occupation. Most members of the community upheld that, there are changes in livelihood activities in the study area characterized by a shift from fishing to trading, farming and artisanry. Majority of the people are relatively poor; only 10% earn N51, 000.00 and above per month. About 88% of the population depend on only 12% of the active labour force in the study area.

Infrastructural facilities and Quality of life

Infrastructural facilities available to the communities include roads, 37% of which are tarred. There are opportunities for water transportation with over 8 functional jetties. Other amenities include those in education, heath, water and sanitation, electricity, markets and recreational facilities. Telephone network providers include MTN, Airtel, Glo and 9-Mobile and over 85% of the residents own private phones. Sanitation facilities are poor. About 75% of domestic waste were disposed in nearby bushes while human wastes were disposed in water bodies.

Housing Type, Pattern and Quality

About 74% of the population live in their houses while 26% live in rented apartments. The common types of housing in the area include those with bamboo walls and thatched roof, brick walls with zinc roof, bungalows and storey buildings. About 48% of the population live in plank wall and mud walls with thatched and zinc roof while approximately 36% of the population live in zinc and brick walls with thatched and zinc roof and about 10% in modern bungalows and duplexes. Few households (6%) live in storey buildings. About 65% of households have between 5-8 persons in a given household while 35% have 1-4 persons and 10% have 9 persons and above respectively in a given household.

Perceptions and expectations of the communities regarding the project(s)

The general disposition to the proposed project by the community members is predicated on positive benefits including award of scholarships, employment and payment of compensation to deserving communities. They expressed fears that the project might lead to spills and pollution resulting in the reduction in quality and species of fishes in the onshore and near shore areas amongst others. They requested that SPDC implements its Global memorandum of understanding GMoU model with the stakeholder communities in the coastal area particularly with regards to employment and infrastructure provision.

Health Profile

Maternal and child health

The focus group discussants reflected that the use of contraceptives was low among women of child-bearing age in the host communities of the proposed project area. High maternal mortality rates in the communities was also a thing of concern to the discussants and this was attributed to lack of good health facilities in the area and midwifing of births by traditional birth attendants. From literature review, delivery by skilled attendants reveals that only 12.3% in Bayelsa and 17.0% in the Rivers had their childbirth attended to by qualified health care providers. Also, neonatal mortality is estimated at 29 per 1000 births attributed mainly lack of qualified birth attendants. Infant mortality rate is estimated as 57 per 1000. The low rate being linked to improvement in childhood immunization and management of childhood diseases. However, discussants at the Focussed Group Discussion muted that inadequate immunization contributes highly to infant morbidity and mortality in their communities.

Health care facilities

Orthodox healthcare facilities are lacking in the area as attested to by the discussants. This is as a result of razing down of existing ones during various communal conflicts. People depend on poorly equipped patent medicine stores, traditional medicine practitioners and traditional birth attendants for health-seeking. Secondary and primary health care facilities are in distant towns such as the Abonnema and Degema General Hospitals.

Disease Pattern and prevalence

Malaria, febrile convulsions, respiratory tract infections, diarrhoea, skin lesions, worm infestations, measles, and neonatal tetanus are common among the children while malaria, hypertension, stroke, diabetes mellitus, arthritis, pregnancy-related complications, chronic liver disease, tuberculosis, asthma and chronic respiratory tract infections, eye problems, inguinoscrotal hernia, peptic ulcer, injuries, burns, and toothaches, etc, are common causes of illness among the adult population. Malaria was the leading cause of morbidity in the community and the discussants expressed a dire need for Long Lasting Insecticidal Nets for prevention. Lack of potable water supply in the communities was pointed to as the cause of diarrheal and skin diseases among residents.

Social and Lifestyle Issues Affecting Health

Many lifestyle choices make significant contributions to state of health among the community members. Notable among these are excessive consumption of alcohol, marijuana and cigarette smoking , increasing use of hard drugs, and sexual risks. It was generally agreed that a little less than half of adults in the communities indulge in alcohol use, while condom use to prevent sexually transmitted infections was not well adhered to. Most people were said to be aware of HIV and its mode of spread.

Environmental Health

There are no water projects in any of the host communities. Available sources of water supply are hand-dug (shallow) wells, rainwater and packaged (sachet) water. There are occurences of diarrhoeal diseases in the area which may be linked to poor water sources. Only few respondents from College Kiri in Francis Okpoama responded positively to availability of borehole water-source in their community.

There is no organized system of solid waste collection and disposal in the area. Most wastes are dumped in the open and along the shorelines. Sewage disposal is through the jetty toilet system characterized by the open discharge of human waste into the rivers and creeks. Such disposal techniques provide a veritable source of infection in the community, especially among children with poor hand washing practices.

Cooking by households is done using adulterated kerosene, firewood, and charcoal. Several health risks and hazards are associated with the use of firewood as cooking fuel in homes. Those at high risk include people with existing respiratory and cardiovascular conditions Firewood burned indoors, produces toxic fumes that threaten the health of inhabitants.

Residents complained of repeated respiratory tract diseases, especially among the children and very elderly persons, which they believe are associated with the poor air quality in the area. Noise levels in the communities often arise from engine boats and helicopter flights. Otherwise, most places in the area are near pristine by noise levels.

Communities' Perception of the Proposed Project

The people view the proposed project as beneficial, and a catalyst for development in their communities. They believe that the project will bring some infrastructural development in the area such as connecting roads, electricity, water projects, health care facilities , erosion control initiatives, etc. The focus group discussants also believe that the project will provide new jobs opportunities and skills acquisition for them. Anticipated negative view about the project border on oil spills which may contaminate their river and affect their fishing business.

ES 15.0: Potential and Associated Impacts

The assessment of the degree of alteration to natural conditions of the aquatic environment from the proposed project activities. The negative impacts would 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:

- Risk of accident from vessel collision
- Risk of Piracy & kidnapping
- Risk of increased activity of Commercial Sex Workers
- Impairment of Air quality
- Increase in noise and vibration
- Aggregation of bottom sediment
- Fish-kills during piling activity
- Risk of accident from dropped objects and structural failures
- Impairment of water quality (turbidity and suspended solids)
- Injuries and death from failure of BOP and explosion
- Impairment of water and sediment quality from accidental release of hydrocarbons, drill cuttings;
- Increased waste volumes - drilling cuttings and muds.
- Smothering of benthic flora and fauna.

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

- Opportunities for business and employment
- Increased oil production
- Revenue generation to government and company
- Employment and income generating opportunity

ES 16.0: Mitigation Measures

To ensure adverse and unprecedented impacts are mitigated to ALARP, the following mitigation measures shall be applied: SPDC shall ensure

- Compliance with journey management policy marine transport
- Adequate radio communication between offshore installations, merchant ships and standby vessels
- Communication hardware and agreed Global Maritime Distress and Safety System (GMDSS) procedures are effective
- Regular drills on abandon ship procedures shall be enforced
- Safety signages shall be deployed at strategic locations.
- Health awareness and sensitization talks on Sexually Transmitted Infections, amongst others
- Use of appropriate PFDs by the survey team.
- Proper identification and management for all security threats and risk are highlighted
- Develop adequate security strategy, plan and procedure for the project.

- Ensure that security orientation and awareness/drills are conducted for the workforce
- Make all necessary arrangements with Government security agents to improve security.
- Develop security management plan for the project before mobilization.
- Ensure all countermeasures to mitigate identified threats are in place.
- Ensure project nonproductive time are reduced to the barest minimum.
- Regular drills are conducted.
- All movements shall be undertaken only with Security Single Point Approval
- Movement shall be under a GSA armed escort
- Use only pre-mobbed and regularly maintained vessels, generators and other machines.
- Use only low Sulphur containing fuels and low NOx burners in large generators and turbines.
- Ensure wet scrubbers and venturi techniques are fitted at the end of pipe for generators and vessel exhaust systems

ES 17.0: Environmental Management Plan

A specific Environmental Management Plan (EMP) has been designed to articulate overarching and specific strategies including plans to assure environmental and social acceptability of the proposed project. It provides the guiding principles, management structure, roles and responsibilities communication strategy and other commitments to achieve the project's HSE goals including regulatory compliance. For each potentially severe impact (high or moderate severity), the EMP identifies and describes monitoring requirements. Specific mitigation and monitoring requirements that are peculiar to the project will be incorporated into the existing HSE-MS and associated plans as appropriate.

ES 18.0: Conclusion

The Environmental Impact Assessment Studies of the JK Exploration and Appraisal Wells Project was conducted in accordance with relevant local, national and international regulations and guidelines. The methodology applied for the study involved a two-season field work, laboratory analyses and extensive stakeholder's engagement exercise. To achieve this objective, a multi-disciplinary approach was adopted in the assessment of the environmental status and sensitivities of the various biophysical, social and health profile of coastal communities. The JK Exploration and Appraisal Wells Project provides an opportunity to appraise the discovered oil and gas resources and explore for new hydrocarbon resources (HC) in the JK field. The well discovered in-place volume of 201 MMSTB and 52 Bscf. This opportunity will boost the Federal Government and SPDC's oil and gas production targets, increase foreign exchange earnings and develop in-country capacity. Other positive impacts of the proposed project include but not limited to the following: increase in business opportunities and Opportunity for contracting.

Furthermore, the baseline data revealed the high carrying capacity of the aquatic ecosystem, rich biodiversity resources and near pristine airshed within the project area. The social and health profile of coastal communities revealed high expectations with regards to employment opportunities, scholarships and social investments.

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.

Acknowledgment

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CHAPTER ONE
INTRODUCTION

1.1: Background Information

The Shell Petroleum Development Company of Nigeria Limited (SPDC) on behalf of its Joint Venture Partners (Nigerian National Petroleum Corporation, Total Exploration and Production Nigeria and Nigerian Agip Oil Company) plans to appraise the discovered oil and gas resources and explore for new hydrocarbon resources (HC) in the JK field in OML 74 SPDC acreage. The exploration and appraisal drilling campaign is part of the Shallow Water Opportunities (SWO) development. The opportunity involves the drilling of 12 notional wells with average depth of penetration within ~ 10,000 to 13,000ft within an average water depth of 20 to 40m. The well discovered in-place volume of 201 MMSTB and 52 Bscf. This opportunity will boost the Federal Government and SPDC's oil and gas production targets, increase foreign exchange earnings and develop in-country capacity.

Early exploration in the vicinity of the JK prospect involved vertical wells testing prospects matured on 2D seismic of mid 1960's vintage with 3 marginal oil discoveries (JD, JK, JO), 1 Minor gas discovery (KF-1) and 3 dry holes (JO-2, JN-1, JA-1). The JK-3 well was drilled in 2004 as a deviated fault scooper and tested the footwall closure of the JK-G prospect down to the base of the F-sands package and discovered 201 MMbbls of oil in place.

Following the potentials for interactions of the project activity with sensitive biological resources and environmental matrix within the project area, SPDC subjected this project to the DPR EIA process inline with the provisions of the Environmental Guidelines and Standards for Petroleum Industries in Nigeria (EGASPIN, 2018) and FMEnv EIA Procedural guidelines. The initial conceptual stages of the EIA have been completed with active participation of relevant stakeholders across Rivers and Bayelsa States and regulators and approval of the Terms of Reference (ToR) and completion of a two season Field Data Gathering (FDG) exercise. 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 tailored mitigation measures to manage environmental risk to ALARP. The findings are hereby incorporated in this report.

1.2: EIA Objectives

The objectives of the EIA are to:

- Acquire baseline data of the environment as well as the socio-economic and health conditions of the neighbouring coastal 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 JK Field is located in the western end of SPDC shallow offshore in OML 74 (J Block) and approximately 26km from Nigeria's coastline. Water depth around this concession is about 25 to 32 meters. The JK field is part of the H block (HB, HA, HD fields) macro structure with a regional northwest – southeast structural trend, offshore, Akuku Toru and Degema and Brass Local Government Areas in Rivers and Bayelsa States, Nigeria. The geographic profile in Minna Mid Belt lies between 382074E, 30667N; 403471E, 30633N; E403531, 27246N; E432078, 27099N; E432400, 754N; E381840, 431N; 432175E, 18712N; E470033, 18597N; E470018, 63N; and E432386, N400.

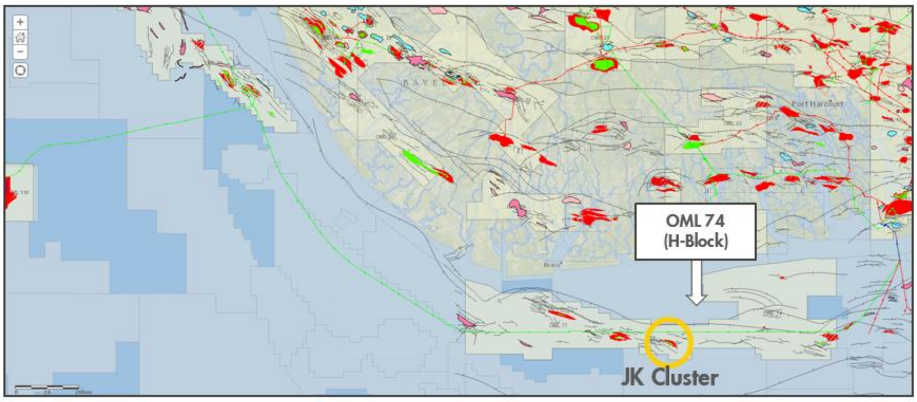

Fig 1.1: Map of the Area of Interest of the JK field in OML 74

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: 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.

1.4.2: 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 FMEnv) 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.

Petroleum (Drilling and Production) Regulations (1969)

The Petroleum (Drilling and Production) Regulations (1969), empowers the holder of an OPL to do practically anything in the area covered by the license {Section 15 (1)}, but Section 15(2) holds such a holder responsible for all the actions of his agents and contractors.

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.

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.

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

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.

FEPA (Now FMEnv) National Guidelines for Spilled Oil Fingerprinting (Act 14 of 1999)
This provides guidelines for spilled oil fingerprinting applicable throughout Nigeria, in order to improve the quality of the environment and to free it from pollutants and other environmental and health hazards.

FEPA (Now FMEnv) National Guidelines on Waste Disposal through Underground Injection (1999)
These Guidelines and Standards on waste disposal through underground injection provide the '*modus operandi*' for the most viable options for disposal of these wastes in a tropical environment as Nigeria.

1.4.3: 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

1.4.4: Environmental laws and guidelines 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.
- Bayelsa State Land Use (Environmental Degradation/Protection) Charge Law 2005.

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 other 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 coastal 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 Coastal communities.

The implications of implementing this policy are that,

- All activities shall be analysed 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) Social Performance/Community Relations Policy

In order to pursue mutually beneficial relations with coastal 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 coastal 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 JK 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 JK 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 was prepared in line with the DPR and FMEnv approved format as shown 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** - Conclusion and Recommendations.

CHAPTER TWO
PROJECT JUSTIFICATION

2.1: Introduction

The JK Cluster is in the western end of OML 74, and it contains one of the largest discovered fields (JK-G) within the license. Early exploration in the vicinity of the JK cluster involved the drilling of two vertical wells: JK-001 in March 1967 followed by JK-002 in April 1967. JK-001 and JK-002 were drilled based on 2D seismic data and found thin oil columns. Subsequently, the JK-G block was discovered in 2004 by the well JK-003. This successful well was drilled based on good quality 3D seismic with direct hydrocarbon indicators. There has been no oil or gas production from the field to date, as none of the wells have been completed or production tested. There are currently no existing surface facilities in the JK field. JK-P is the first of several wells planned to further explore the shallow water in the JK area starting in 2020. There will be about four other planned exploration and appraisal wells around the JK field following the first JK-P well. JK is seen as an oil-rich development opportunity with significant opportunities for growth and an exploration campaign is on-going with the aim to discover more volumes to ensure the oil development is investable and attractive. With an execution window of Q1 2020 to Q4 2021, SPDC is well positioned to appraise the discovered hydrocarbon resource in the JK field. This subsection highlights the Project overview, Project scope, Project activities and Options/Alternatives.

2.2: Need for Project

This exploration activity is to support JK-HD cluster development. The JK-3 discovery has appreciable resources with additional potential for the project to meet relevant portfolio screening criteria. The proposed JK exploration wells are expected to discover some of this volume and feed key development decisions including concept select for frontrunner oil scheduled for Q2 2021 and DG 3 in Dec 2021. Delivery of these wells is on the critical path, as DG3 acceleration on JK is strongly dependent on early availability of the exploration/appraisal drilling results.

2.3: Benefit of the Project

The project will be executed under the legal structure of the existing SPDC joint venture with the Nigerian National Petroleum Corporation (NNPC). In a success case, these exploration wells will drive the development of the field with expected revenue from the sales of oil to be produced from the field. The financial proceeds will substantially increase the foreign exchange earnings of the Federal Government and help to improve the social and health standards of the neighbouring coastal communities around the OML74 area covered by the project. The exploration and appraisal drilling will also provide job opportunities for people around the neighbouring coastal communities.

2.4: Envisaged Sustainability

2.4.1: Economic sustainability

The economic sustainability of the proposed field development in a success case exploration is high. The project will increase SPDC oil production and deliver cash to all the entities in the

SPDC JV. The oil potential of the JK cluster can economically support the project increasing contribution to the revenue accruing to Nigeria and SPDC JV partners.

2.4.2: Technical Sustainability

The proposed project is technically viable as it will rely on existing and well-established technologies, with proven oil field experience and strong HSE awareness. The design and operation of the Wells would be carried out in line with national and international codes and standards of practice. Innovative technologies that are economically viable and having minimal environmental, social and health impacts shall be utilized in the execution of the proposed project. In addition, personnel with experience in similar operations will be involved in the transition and early operations.

2.4.3: Environmental Sustainability

The findings and recommendations of this EIA would be integrated into all phases of the proposed project lifecycle. Recommendations on the project process, waste management (handling, treatment and disposal) which were developed in line with the environmental regulations, guidelines and standards of the Federal Ministry of Environment and Department of Petroleum Resources as well as international best practices would ensure the environmental sustainability of the proposed project.

2.5: Project options

The development for the Shallow Water Opportunities are centred on optimal well placements, and timing of new wells. Scenarios focus on several alternatives with a view to optimizing well placements and the drilling sequence to maximize recovery in view of the key value drivers for the project. This section presents the various development concepts for the JK Exploration and Appraisal Wells Project opportunity. The project options are presented in Table 2.1. The project options considered for the JK exploration and appraisal well project are:

- No Project Option
- Delayed Project Option
- Drill Wells

The advantages and disadvantages of each project options are presented in Table 2.1.

Table 2.1: Project Options considered

Option	Advantages	Disadvantages	Remarks
No Project Option	• No capital expenditure • No new risks • No impact on the environment	• Major loss of potential revenue and opportunities for Nigeria by locking in hydrocarbon resource and stalling human/infrastructure development opportunities.	Not Recommended
Delayed Project Option	• More time to plan and assess risks	• Delay in achieving First Oil/Gas Date • Loss of expected revenue for that period of time to Government and SPDC	Not Recommended
Drill Wells	• Increase revenue to the government and SPDC • Strong developmental pull to the JK field; • Explore the identified Deep HC opportunities. • Improve economy of coastal communities.	• Increase in the Environmental footprint in the JK field. • High Capital Expenditure • Increased pressure on existing socio-economic activities in the field	Recommended

2.6: Project Alternatives

Drilling Location Alternatives

These proposed wells will be deviated targeting multiple levels in the respective prospects and will be drilled with a Jackup Rig. In order to find the optimum number of drilling locations, four critical success factors were used:

- Minimal impact on environment
- Sub-surface targets reach
- Technical doability within HSSE limit
- Project cost vs value

Option 1: Clusters of 3 drilling centres

The option to drill these wells from a cluster (platform) location was considered. However, the outcome is that:

- The wells will be a long distance away from the drilling centers, reducing the chances of success for reaching the target reservoirs at all.
- The wells will have very long high-angle tangent sections with associated Well control risks.
- The wells will have very high cost of construction and operation.
- Low environmental footprint

Remark: Not recommended

Option 2: Individual drilling locations

These multi-level deviated wells will be drilled from respective well locations. The outcome is that:

- All targets can be reached from these respective locations
- The wells would be simple with minimal Well control risks.
- The cost of construction and operation will be lower.
- Localized environmental impacts around the well locations

Remark: Recommended

2.7: Matrix Scoring Process

Selection of the most viable location option is carried out using a documented matrix scoring process. This process utilizes factors categorized as:

- Environmental and Safety Considerations
- Engineering and Operational Considerations
- Constructability

These major categories are sub-divided into smaller elements or criteria to further enhance the objectivity of the analysis. The list below captures the main criteria considered for the JK Exploration and Appraisal Wells:

1. Environmental and Safety Considerations
    - Impact on sensitive environment
    - Impact on natural environment
2. Engineering and Operational Considerations
    - Ease of Access
    - Operational & maintenance concerns
    - Interference with existing or proposed facilities
3. Constructability
    - Location design
    - Construction terrain

The impact of each criterion is ranked by assigning scores between 5 - when the impact is positive, and 1- when it is negative (**Table 2.2).**

Table 2.2: Score description

Score	Description
5	Little/no negative impact or very good to excellent opportunity
3	Minimal negative impact or generally good opportunity
1	High negative impact or little/no opportunity

The pre-determined weight factor is applied to the ranking to get the score for each criterion. The total score for each option is the sum total of the weighted criteria.

Table 2.3: Surface location options ranking for the JK Exploration and Appraisal Wells Project

Well location Selection criteria		**Environmental and Safety considerations**			**Engineering and Operational considerations**					**Constructability**				**Remark**
Assessment factors		Sensitive Environment	Impact on Natural Environment	**Subtotal**	Ease of Access	Operation and Maintenance	Fac. Interface (pipeline etc.)	Drilling risk mgt.	**Subtotal**	Location design	Construction Terrain	**Subtotal**	Total Score	
Weighting scale		15	10	35	10	5	5	5	35	10	20	30	100	
Option 1 (Individual drilling locations)	Ranking	1	5		5	5	5	5		5	1			1st
	Weighted score	15	50	**65**	50	25	25	25	**125**	50	20	**70**	260	
Option 2 (Clusters of 3 drilling centres)	Ranking	1	5		3	3	5	3		5	1			2nd
	Weighted score	15	50	**65**	30	15	25	15	**85**	50	20	**70**	220	

CHAPTER THREE
PROJECT AND PROCESS DESCRIPTION

3.1: Introduction

The business driver is to prove new non-associated gas reserves to utilize ullage in the JK cluster and meet NLNG supply obligation. The details of the scope of work, proposed project activities and Waste Management in the JK field is presented in this chapter.

3.2: Project objectives

The objective of the JK Cluster Exploratory and Appraisal Wells Project includes:

- Explore the identified HC opportunities around the JK field
- Appraising the discovered HC resource in the JK field.
- Supports the Federal Government and SPDC's oil and gas production targets.
- Monetizing the newly renewed blocks.

3.3: Project location

The JK Field is located in the western end of SPDC shallow offshore in OML 74 (J Block) and approximately 26km from Nigeria's coastline. Water depth around this concession is about 25 to 32 meters. The JK field is part of the H block (HB, HA, HD fields) macro structure with a regional northwest – southeast structural trend, offshore, Akuku Toru and Degema Local Government Area (LGA) of Rivers State and Brass LGA of Bayelsa State, Nigeria. The geographic profile in Minna Mid Belt lies between 382074E, 30667N; 403471E, 30633N; E403531, 27246N; E432078, 27099N; E432400, 754N; E381840, 431N; 432175E, 18712N; E470033, 18597N; E470018, 63N; and E432386, N400.

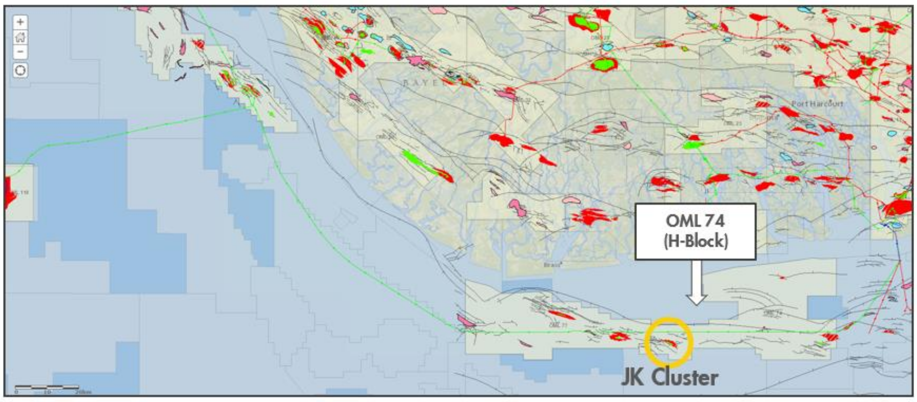

Fig 3.1: Map of the Area of Interest of the JK field in OML 74

It should be noted that even if JK is developed first, from technical point of view, the field layout could remain unchanged, i.e. WHP at JK and PP location at HD. The influencing parameter would rather be whether FID would be taken for HD and JK or for JK only.

3.4: Project scope

The scope of the JK Exploration and Appraisal Wells Project is to:

- Test the fault block south of the JK-3 drilled block for commercial quantities of hydrocarbons, gathering data for field appraisal and development. The primary targets are D7000, D9000, E1000, E3000, F1000.
- To support JK-HD cluster development. The JK-3 discovery has 2C resources of approximately 100 Mmbbl UR, with an estimated additional 70 MMbbl oil UR required for the project to meet screening criteria (Post FID VIR >0.5). The proposed JK-P exploration well is expected to discover some of this volume and feed key development decisions: "Concept Select for frontrunner oil" in Q2 2021 and DG 3 in Dec 2021. Delivery of these wells is on the critical path, as DG3 acceleration on JK is strongly dependent on early availability of the exploration/appraisal drilling results
- If successful, the well would be safely suspended. This would be followed by completion and hook-up as specified in the notional development plan. The JK campaign will involve the following:
- Drilling 12 Exploratory/Appraisal wells with a Jack-up rig in shallow waters of between 20m and 40 water depths in OML 74 of SPDC acreage.
- Planned to drill, plug back and suspend the exploration / appraisal wells.
- Some of the appraisal wells may be optimized for development/producer wells in the project life cycle and may be side-tracked.

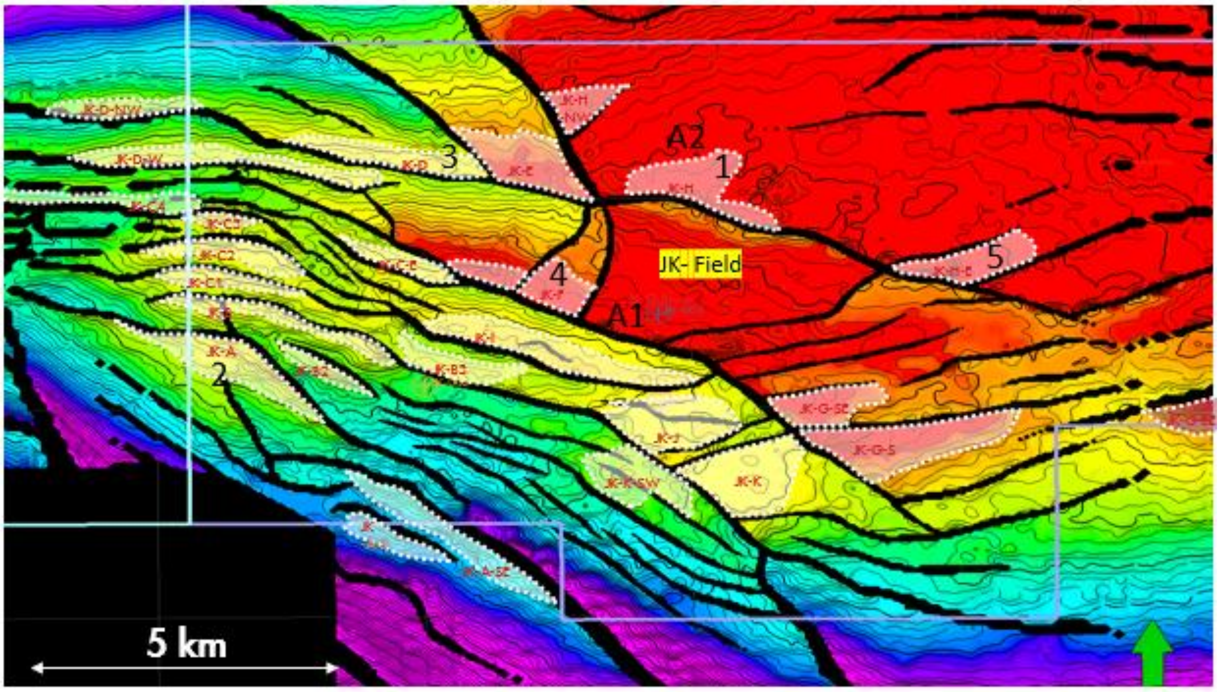

Fig 3.2: JK Field and surrounding Prospects/Leads showing notional locations

Types of Wells

A total of 12 Wells are planned in the JK Well cluster - 9 development Wells, 2 Exploration/Appraisal Wells and 1 CRI Well. Details of the JK well inventories and coordinates are presented in Table 3.1 and Table 3.2.

Table 3.1: The JK well inventory

		WELLS	SLOTS†
INITIAL DEVELOPEMENT - PHASE I			
	JK-G Appraisal Well (SMART 1)	1	1
	CRI Well	1	1
	D9 Horizontal	3	1.5
	D7 Horizontal	1	0.5
	E3 Horizontal	3	1.5
	E3 Deviated	1	0.5
	SMART 2 (E3-D9-F1-F deep)	1	1
	JK-I Appraisal Well (D7-D9-E3 Smart)	1	1
Sub Total (Combo Smart)		12	8

Table 3.2: Well prospects and coordinates in the JK field

S/N	Prospect Name	X	Y
1	Block-A	449258	8820
2	Block-C (Mini Cluster)	449555	10400
3	Block-D	451977	12904
4	Block-E	453693	12570
5	Block-H	456053	12308
6	Block-HE	460367	10686
7	Block-F	453812	10232
8	Block-G	454909	9660
9	Block-GS	458249	7394
10	Block-I	453717	9254
11	Block-J	456005	8038
12	Block-K	456601	6726

3.5: Project activities

The specific major activities of the proposed project to be carried out include

- Premobilization
- Mobilization
- Drilling;
- Waste management.
- Demobilization;
- Maintenance of well-head; and
- Decommissioning and abandonment.

3.5.1: Premobilization phase

The activities in this phase will be essentially desktop, feasibility, environmental, technical and financial considerations. These investigations are aimed at ensuring the viability and sustainability of the project while having minimal negative impacts on the environment. The results of these investigations will culminate in the preparation of a detailed drilling, casing and mud program. The operating environment was taken into consideration in deciding the type of drilling fluids most suited for the project. Consultations and meetings with stakeholders (regulatory bodies, government agencies and contractors) are prominent features of this phase. These consultations ensure that all stakeholders are notified and carried along the proposed project activities. The benefits of these meetings/consultations are to ensure that the wells drilling, and development are carried out with stakeholders' issues and concerns taken into consideration.

3.5.2: Mobilization

Materials and equipment that shall be transported during the mobilization phase include:

- The rig;
- Pipes and casing and
- Drilling chemicals.
- Personnel

As much as it is reasonably practicable, mobilization for the well drilling and development campaign activities shall be sequenced to maintain minimum site presence as well as exposure to personnel, equipment and resources.

3.5.3: Drilling phase

Conceptual and detailed design of Wells

The conceptual design is such that the development will be executed in two phases. Phase 1 involves drilling JK-P exploration & appraisal wells in 2020, 3 development wells and completions in 2028 and 3 recomplete in 2033, then drill JK-FG in 2020 to appraise west of JK-3 block (existing discovery), drill and complete 2 development wells in 2028. Finally, the WHP1 will connect JK-3, JK-P, JK-FG and JK-O development wells.

The well is planned to be initially suspended for future completion based on the notional development plan. The plan for JK Cluster Deep-1X is to complete the reservoirs using a bottoms-up philosophy. The completion design is a case and perforate completion configuration with a tubing retrievable surface controlled subsurface safety valve and a permanent down-hole gauge. The perforations would be achieved under-balance with a tubing conveyed perforation system and the well completed with a 4½", 13Cr corrosion resistant alloy tubing and nickel-based alloy for the tubing accessories. The key features of the preferred completion scheme are as follows:

- Surface Safety Valve
- Permanent Down-hole Gauge
- Tubing Conveyed Perforation

- Surface Sand Detectors.

Although this completion scheme does not provide down-hole sand production protection, it is a simple and robust design similar to that planned for Gbaran-26 and has a high chance of being successfully deployed.

The JK well design has been performed in accordance with Shell group requirements and in line with SPDC policies. There are two casing scheme designs (conventional and reduced casing schemes). The conventional casing design consists of four strings (36" conductor, 22" surface casing, 13 5/8" intermediate casing and 10 ¾" x 9 ⅝" production casing). The reduced casing design consists of three strings of casing (36" conductor, 22" x 13 5/8" surface and 10 ¾" x 9 ⅝" production casing, with no intermediate casing). A contingency 7" casing will be carried for either casing schemes. A summary of the specifications of the various casing types planned for the JK Wells is outlined in the Table 3.3. All casings that would be exposed to hydrocarbon bearing formations during well construction or production will be required to have gas tight (premium) connections in line with the Shell Group well design standards.

Table 3.3: Wells Casing Summary

Parameter	Conventional Casing Scheme
Conductor	36'' 1.5 / 1.0'' X65
Surface Casing	22'' 224ppfX56
Intermediate Casing	13-5/8''88.2ppfT95
Production Casing	10 3/4'' 60.7ppfT95 x 9 5/8'' 3.5ppfT95 XO just below where the SCSSV will be installed
Contingency Casing	7''29ppfL80 (for wells up to 12,300ft tvdss) or T95 (Recommended for deeper wells, since L80 will fail under the full evacuation load case)

Drilling and Completions Hazards

Seabed and shallow hazards that may be encountered in the area include shallow water flows, shallow gas, seabed hydrates, losses and borehole instability. Hazard management will primarily focus on verification that planned activities are adequately robust to cater for possible outcomes at various locations, while additional precautions will be taken during execution of drilling and completion operations, to reduce any remaining risks to acceptable levels. Specifically, the near-seabed formation will be properly assessed for shallow hazards and mitigating plans shall be incorporated in the drilling and completion plans (Fig. 3.3) to prevent undesired outcomes.

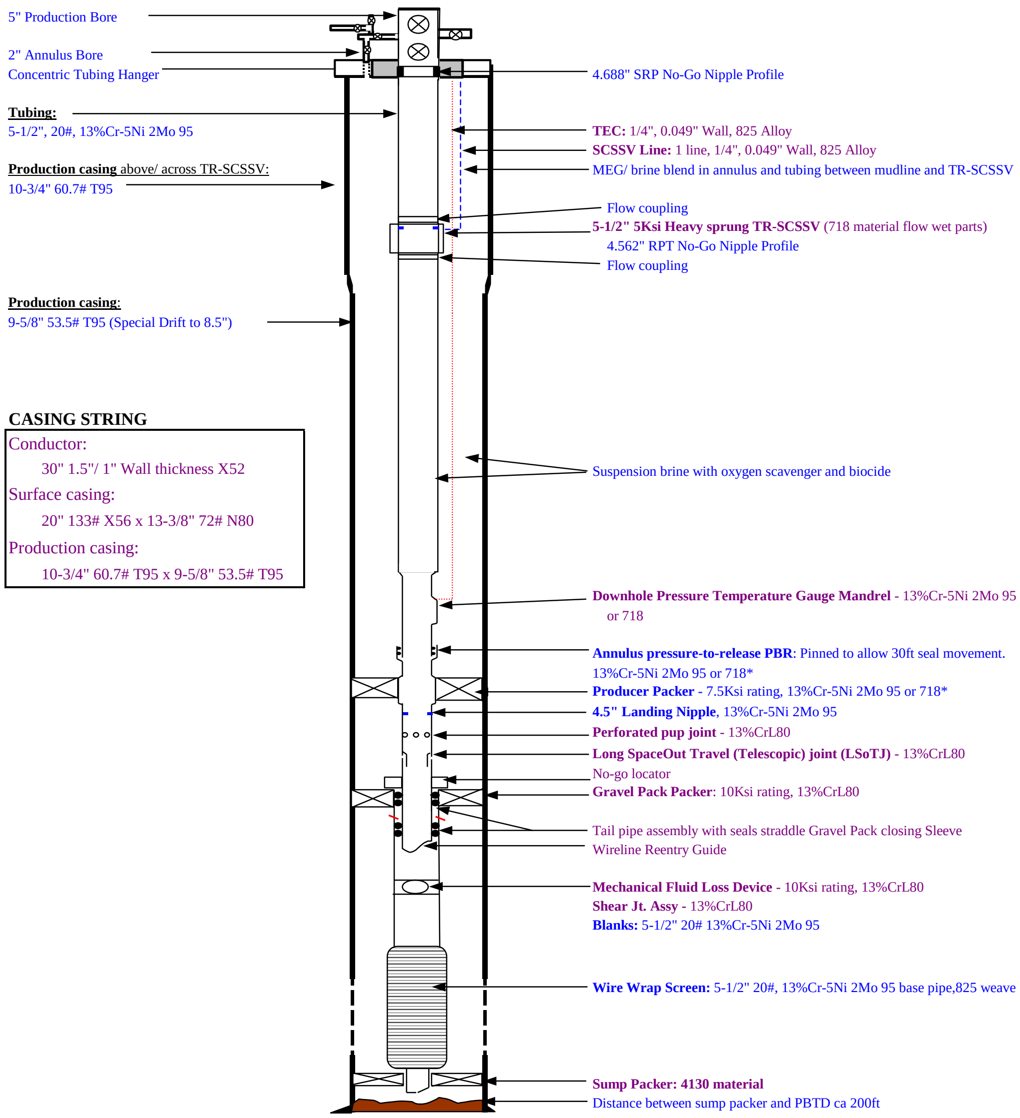

Fig. 3.3: Producer Well architecture of the JK drilling campaign

Subsea Wellhead

A standard sour service, guideline-less subsea wellhead system with the appropriate connector profile shall be utilized. The wellhead system shall consist of 36" low-pressure wellhead housing and conventional 18¾" nominal bore subsea high-pressure wellhead system. The wellhead system shall be compatible with the selected BSWA subsea tree system (subsea tree & Tubing Head Spool (THS)) and Tubing Hangers (TH). The design basis for the wellhead shall include but not limited to the following as shown in Table 3.4.

Table 3.4: General Design Criteria for Wellhead Systems

Parameters	Values
Drilling and Completion Fluids	Sea water, KCl-Polymer, Silicate, Mineral Oil Based Mud, Synthetic Oil Based Muds, NaCl Saturated Drill Fluids
Produced Fluids	
Wellhead Design pressure	10,000 psig minimum, 15,000 psig optimum
Wellhead CITHP Estimated	3,880 - 4,807 psig
Wellhead Shut-in Temperature	4^{o}C (40°F) min (seawater)
Wellhead Operating Temperature	4^{o}C – 80^{o}C (40°F - 176°F)
SCSSV Type and Number	TRSCSSV (one per well)

Borehole Stability

Exploration, appraisal and development well drilling experience and other deep-water wells in Niger Delta have confirmed the existence of wellbore stability issues in shale formations. This phenomenon has also been reinforced by laboratory studies carried out by Shell's Bellaire Technology Centre (BTC). BTC studies confirmed the feasibility of drilling wells up to 90 degrees inclination with appropriate mud properties, and this has been proven in deep development where horizontal wells were drilled successfully. The results of BTC studies and experience gained on exploration, appraisal and development drilling in deep waters shall be incorporated in the well design.

Drilling mud system

The mud weight for the JK Wells shall be determined based on the pore pressure/frac gradient prediction for the wells. Drilling operations require the use of a special drilling fluid (mud). The mud is continuously pumped down the 'drill string' to the 'drill bit' and returned to the surface through the space between the drilling string and bore hole. Summarized in Table 3.5 is the drilling mud selection for the proposed project. Drilling mud performs the following functions:

- Exerts hydrostatic pressure on the down hole and prevents formation fluids from entering the wellbore.
- Removes drill cuttings from the bottom of the hole and carries them to the surface and when circulation is interrupted, it suspends drill cuttings in the hole.
- Lubricates and cools the drill bit and drill string.
- Deposits an impermeable cake on the wall of the 'well bore' effectively sealing and stabilizing the formations being drilled.

Table 3.5: Drilling Fluid Selection for the JK Wells campaign

Hole Sections	Drilling Fluid Selection		
	Wells < 40°	**Wells > 40°**	**Horizontal Section**
Top-hole	Seawater with regular Bentonite Gel sweeps	Seawater with regular Bentonite Gel sweeps	Not applicable
Intermediate	WBM/SBM	SBM	Not applicable
Réservoir (production)	SBM	SBM	Synthetic/Calcium Chloride-Glycol

Well Operations Sequence

In view of its efficiency, batch drilling and completion operations are planned. This shall allow pre-drilling of a number of wells, prior to delivery of certain long lead items, such as tubing head spools, vertical subsea trees, tubing hanger and work-over riser. In addition, batch operations shall allow realization of a number of operational efficiency gains. Simultaneous Operations (SIMOPS), appraisal strategy and data acquisition shall be taken into consideration in the Wells sequence.

Drilling Unit

The Jackup rig shall be used for the JK Wells drilling campaign. Rig is built on a floating hull that must be moved between locations with tug boats. In location, jack-up rig is raised above the water on legs that extend to the seafloor for support. Jack-ups can operate in open water or can be designed to move over and drill though conductor pipes in a production platform. Rigs come with various leg lengths and depth capabilities (based on load capacity and power ratings). They can be operated in shallow waters and moderate water depths up to about 450 ft.

Plate 3.1: Typical Jack up rig planned for the JK Wells drilling campaign

Source: IADC, 2001

Well Completions

The critical success factors for well completions shall include but not limited to the following;

- High well productivity and injectivity to satisfy production requirements;
- High ultimate recovery per well, to minimize the total number of wells during the life of the field;
- High well reliability, to minimize the workover frequency and to maximize well deliverability.

Well Clean-Up

The wells will be cleaned up using coiled tubing assembly 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 the 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.

Surface Controlled Subsurface Safety Valve (SCSSV)

A Tubing Retrievable Surface Controlled Subsurface Safety Valve (TR-SCSSV) shall be utilized on completions. The valve shall be a non-balanced, heavy sprung, non-equalizing type. A dual control line is being considered, but not the base case. The methanol injection line to the subsea tree shall be sized to enable equalization of the valve. Also, there is an option being considered to use a nitrogen dome charged valve. The valve will be 5-½" designed with the capability for an insert valve. The valve will be set below the hydrate formation depth (approximately 2,000 ft below mud line) to avoid becoming inoperable due to hydrate formation. This will ensure that hydrates will not form at the SCSSV irrespective of how long the well is shut-in. The operating envelope should encompass all aspects of installation through well operating conditions with a minimum control line operating pressure specified in the Wells Basis for Design.

Fluids and Discharge

- The drilling fluid selection has been based on the need to achieve operational, environmental and regulatory compliance. To this effect, the top-holes will be drilled with seawater while the hole sections below the top-hole will be drilled with synthetic based mud. Synthetic based mud will be used to drill JK development wells to ensure successful drilling operations. The drilling fluid is expected to fulfil operational and regulatory requirements; and also meet Shell Group Global Environmental Standards.
- Currently, the synthetic based oil on cutting discharge permitted offshore Nigeria is limited to 5% , and cuttings drier technology has been used in addition to other standard solids control equipment to treat the cuttings within the regulatory requirements, that ensures compliance with legislation. The rigs for the drilling of the JK wells will be equipped with standard solids handling and treatment facilities including cuttings drier.

Artificial Lift

There are currently no provisions for artificial lift in the completion design.

Permanent Monitoring System

A permanent downhole pressure and temperature sensor shall be included in all wells. This allows monitoring of the completion integrity and the reservoir. To enable production monitoring per well, a suitably approved algorithm shall be used. This enables wellhead and downhole pressure and temperature gauges and SP CF to determine flow rate and composition. Downhole flow meters are currently not considered in the downhole completion design.

Suspension Barrier

A mechanical fluid loss device is required to prevent fluid loss to the formation post gravel pack operations and help maintain primary well control. By isolating the completion fluid from the formation, further damage to the well bore / reservoir interface is avoided. The device selected shall contain pressure from either direction with characteristics of reliable closure to reduce brine losses and clean-up periods. It will be utilized to suspend all well types and requires pressure cycles down the tubing string to open.

Sand Control

A variety of sand face completion types shall be used based on the compressive strength of the formations. Failure of the rock occurs at very low differentials affecting both producers and injectors. Sand face completion designs shall be case specific. The sand face completion type for each well shall be chosen based on parameters that can influence the results of the sand control installation, including well inclination and azimuth, sand quality, geological uncertainties and zone configuration (single or multiple).

Well Suspension and Abandonment

Well suspension refers to a temporary interruption in well construction/repair activities with the aim to return to the well at a later date. Abandonment is when all required permeable zones, fluids and pressures are isolated permanently with no intention of ever re-entering the abandoned part of the wellbore. There will typically be two suspensions during the drilling and completion operations. The first suspension will be, after the drilling of each top-hole during batch operations, after setting the 22” or 22”x13-5/8” surface casing. The second suspension will be either after the 9-5/8” production casing has been installed or the 8-1/2” drainage hole has been drilled and lower completion installed. This allows for the BOPs to be retrieved and the THS installed in preparation for upper completion installation. The well design will take into consideration the permanent abandonment of the wells at the end of their life cycle.

Well Blow-out Analysis

The proposed completions have been designed to mitigate the basic risks of loss of control/blowout and ignition/wellhead fire. In the unlikely event of a blowout, a relief well will be drilled to intersect the blowing well at the top of the reservoir with a high kill fluid density of to kill the blowout well. Opportunity exists for further optimization where other locations become available before commencement of the drilling phase. After drilling the top hole with water-based mud (WBM) and the intermediate section with Pseudo-Oil Based (POBM) mud, the reservoir section will be drilled with WBM (Thixal system for gas and carbonate system for oil). This will provide the required overbalance and these sections will be cased off with a 9 5/8" casing or 7" liners or open hole completions. After cementing and testing the casing/liner, the wellbore clean-up will be done by displacement to standard 0.47 psi/ft Calcium Chloride or thixal brine to provide the right over balance. Oxygen scavenger and pH lower than 10 are required to ensure completion integrity. It should be noted that the low annular fluid weight also reduces the downhole completion equipment pressure rating requirements due to lower anticipated differential pressures.

3.6: Relationship with other nearby Projects

Nearby facilities close to the JK Cluster project area includes but not limited to the following:

- Wells: JK-1, JK-2, JK-3 and HD wells. Average depth of penetration of wells in the area is between 10,000ft and 13,000ft.

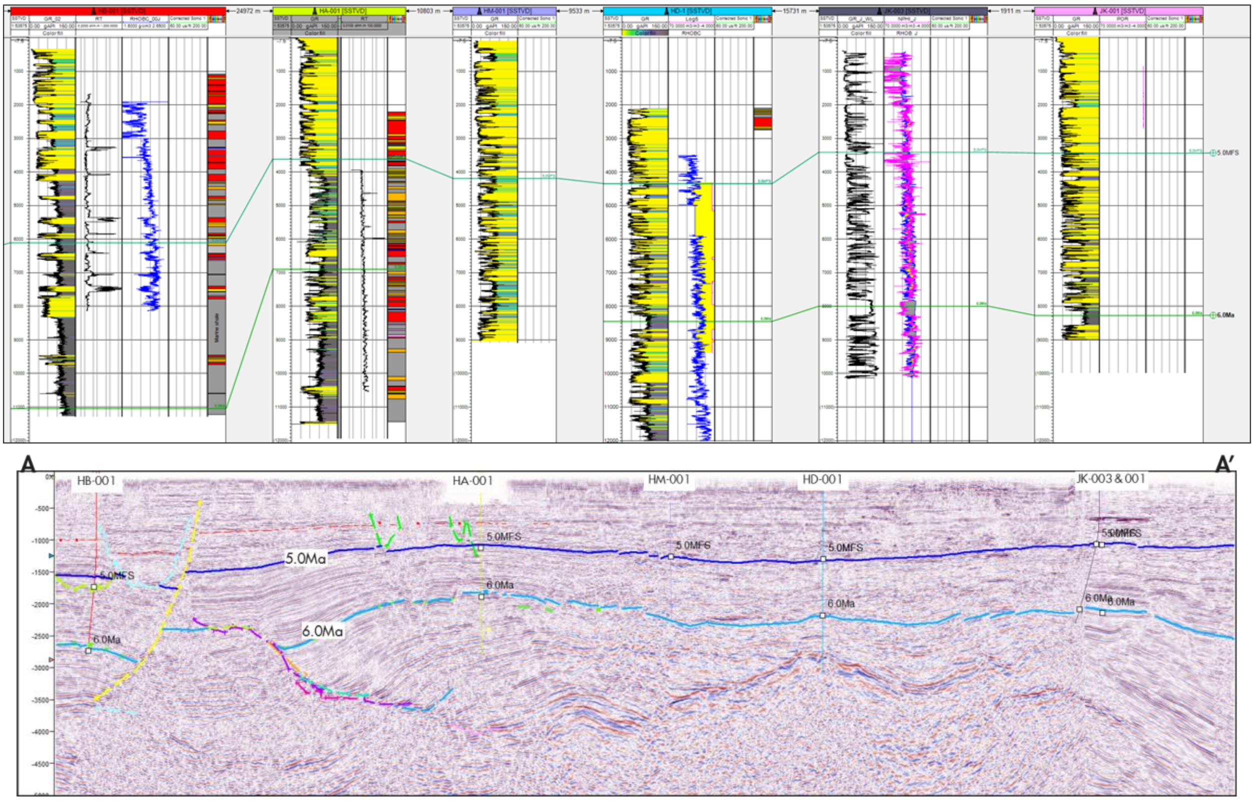

Fig 3.4: Regional HB – HA – HM – HD – JK Stratigraphic Framework

3.7: Decommissioning and Abandonment Plan

The Shell Petroleum Development Company's corporate policy is that all assets including wells which have reached the end of their useful life, shall be decommissioned and either dismantled and removed, or abandoned, in accordance with statutory requirements and the Group standards. Sites shall be left in a safe and environmentally acceptable condition. A risk assessment will ensure that nothing will be left that is a significant hazard for other users of the area or for the environment in general. When the decision is taken to decommission the JK Wells, a detailed Decommissioning Plan will be developed which will consider all feasible options and take account of the then current technology.

Wells

Wells will be plugged and abandoned (note that abandonment and decommissioning are used interchangeably for wells) so as to completely isolate all the hydrocarbon-bearing intervals/sand zones and also return the seabed ~~to~~ as close to the initial state as possible. Water bearing formations which are in pressure communication with hydrocarbons (e.g. down dip of oil or gas) will also be isolated effectively. Downhole equipment such as tubing in the wells will be removed and the perforated parts of the wellbore across the reservoir cleaned of sediment, scale and other debris. Residual hydrocarbons in production wells will be displaced with a high-density fluid and wells will be mechanically and/or cement plugged to prevent fluid migration within the wellbore to the seabed or overlying formations. The subsea trees will be removed and the top of the wellheads will be approximately 3.5m above the seabed. Water depths are over 1,000 m – so this is not expected to pose a hindrance to fishing or navigation. Wells abandonment will be done in accordance with the SHELL Wells. In particular;

- All Permeable Zones penetrated by the well shall be isolated from each other and from the seabed or ground level using one Permanent Barrier as a minimum, unless cross flow between the zones is assessed as acceptable by the Petroleum Engineering discipline and supported by the Department of Petroleum Resources (DPR).
- A permanent barrier shall consist of Good Cement of at least 30 m (100 ft) in length along hole above the highest point of potential inflow, unless the natural distance between permeable zones to be isolated is shorter or a different length is stipulated by the Regulator. This applies equally to the inner bore and all the annuli.
  Elastomers or metal-to-metal seals as used in most mechanical plugs and packers are not acceptable as the sealing element of a Permanent Barrier. This shall also apply to materials used for control lines and downhole electrical cables that pass through the permanent barrier.
- A mechanical device may be used as a pressure control or flow barrier or as a support for the cement slurry but is not considered a permanent barrier itself.

3.8: Waste Management Plan

The Waste Management Plan (WMP) for the JK Exploration and Appraisal Wells Project captures waste identification, characterization methods, storage, tracking, monitoring and audit of the waste disposal sites. Broad strategies deployed to handle wastes from its operations include:

- Treated sewage–Treatment by batch method in a sewage treatment tank using a mix of aerobic bacteria action degrading the solid waste and chlorine to dis-infect the water before discharge to sea.
- Waste Food – Macerated and discharged into the sea.

A specific waste reduction programme that will systematically reduce waste generation to the minimum with a Waste Management Plan (WMP) has been developed for the project. This plan will be integrated with the larger SCiN Waste Management System.

The WMP has been developed to handle all types of wastes that will be generated during various phases of the project. The bulk of waste generated will be from logistics, drilling operations, and decommissioning activities. The anticipated wastes from these activities include domestic wastes (e.g. food and trash), sanitary wastes, spent drill cuttings, used drilling muds, grey water, noxious gases and oily waters. A summary providing types, quantities, and a brief description of the handling strategy for drilling and post drilling is given in Tables 3.6 and 3.7.

Table 3.6: Drilling Waste Types, Estimated Quantities and Corresponding Management Methods

Waste type	Estimated Quantities	Management Method/Strategy
	SOLIDS	
Drill Cuttings	72,000 total bbls of water-based mud cuttings; 58,000 total bbls of synthetic mud cuttings.	Continuous: Drill Cuttings may be discharged overboard by shunting to the bottom provided DPR oil content limitations are satisfied.
Maintenance Wastes	Varies	Intermittent: Includes metal turnings, sock filters, sand blast waste, oily rags, etc. Included in waste-to-shore for recycle or proper disposal.
Rubbish and Trash	650 lb/day (based on 130 POB @ 5 lb /person/day).	Continuous: Consists of paper waste, packaging wastes, etc. Typically included in waste-to-shore for landfill disposal.
Solvent Drums, Paint Cans, Hazardous Solids	Varies	Intermittent: Waste-to-shore; Proper disposal method is secured.
	LIQUIDS	
Drilling Fluids	5,500 bbl/well of water-based mud for top-hole section.	Intermittent: Recycle mud to extinction; Use water-based mud; Waste-to-shore for treatment and disposal.
Deck Drainage	23.67 MMgal/yr (based on annual rainfall of 121", deck area of 79,000 ft^2, and 80% capture rate).	Intermittent: Treat for oil removal and discharge overboard.
Black Water	3,705 gal/day (based on 150 POB @ 28.5 gal/person/day).	Continuous: Treatment system to accommodate 120 operators and 30 temporary personnel. Biological treatment, removal of solids & floatables; disinfect.
Grey Water	4,550 gal/day (based on 130 POB @ 35 gal /person/day).	Continuous: Drain screens to prevent entrance of floatables into collection system.
	GASES	
Burner Boom	CO = 2.16 TPD NOx = 5.18 TPD	Intermittent: Minimize through best practices/ procedures; Smokeless flare design in use.

Waste type	**Estimated Quantities**	**Management Method/Strategy**
	VOC = 4.00 TPD	
Main Engines·	CO = 1.05 TPD NOx = 4.62 TPD VOC = 0.12 TPD	Continuous: Use of low-sulfur diesel fuel; Equipment designed for low emissions; Implement preventive maintenance and inspection program.
Diesel Drivers	CO = 0.19 TPD NOx = 0.85 TPD VOC = 0.03 TPD	Intermittent: Most emissions from exercises and drills; Use of low-sulfur diesel fuel; Equipment designed for low emissions; Implement preventive maintenance and inspection program.
Fugitives	VOC = 0.02 TPD	Continuous: Implement Leak Detection and Repair Program.
Storage Tanks	Negligible	Continuous: Low vapor pressure liquids limit emissions.

Table 3.7: Operations Wastes Types, Estimated Quantities and Corresponding Management Methods

Waste Sources/Types	Operation/Equipment Generating Waste	Volume (Estimated total volume during HUCSU phase)	Frequency of Generation	Waste Classification	Proposed Disposal Options	
					Disposal Method	**Facility Name**
Oil & Grease, Condensate samples from QA testing	Laboratory Hazardous tank Non-hazardous tank Kitchen Grease trap Caisson oil bucket Maintenance activities (turbines, fuel filters, etc.)	6 cubic meters	Intermittent	Hazardous waste	Offsite recycling	FMEnv accredited Facility for treating oil and grease
Domestic Sludge	Sewage treatment plant	500 cubic metres	Daily	Non-hazardous (Biodegradable)	Onboard sewage treatment plant	FMEnv & DPR accredited treatment plant
Oil Contaminated rags, containers, oil filters & other oil contaminated solid waste	Maintenance activities, Spill & Leakage control	250kg	Intermittent	Hazardous waste	Offsite treatment and disposal	
Chemical contaminated containers, filters, paints cans	Workshops, chemical skids, chemical skid	TBA		Hazardous waste	Offsite recycling where possible or disposal by (crushing)	FMEnv accredited facility for cleaning/washing or bioremediation
Expired chemicals, chemical reagents	Chemical skids, laboratory		Intermittent	Hazardous waste	Offsite recycling where possible or disposal by TDU	
Refrigerants	Workshops	(nil during HUC)		Hazardous waste	Offsite disposal	
Scrap materials	Empty drums, used tubular, used casing, electrical cables, used pipeline, used tanks	500 kilograms	Per month	Hazardous waste	Offsite cleaning and re-use	(depending on type of contaminant)
Scrap materials (uncontaminated)	Scaffoldings, metal cuttings, grinding waste, tubular, electrical cables casings	10 tons	Intermittent	Non-hazardous waste	Offsite re-use or recycle	Transported back by contractors to shore for re-use or recycling
Scales/metal oxides	Maintenance works	(nil during HUC)		Hazardous waste`	Offsite disposal	Accredited 3rd party recycling/disposal site
Batteries and fluorescent tubes	Maintenance works	TBA	Intermittent	Hazardous	Offsite disposal	Accredited 3rd party recycling/disposal site
Metal/Tin cans (dried paint cans, coke cans, other uncontaminated cans)	Maintenance works & LQ	One ton per month	Daily	Non hazardous waste (Non-biodegradable)	Offsite recycling	Cans are crushed, compacted and recycled onshore accredited handler

Table 3.7: Operations Wastes Types, Estimated Quantities and Corresponding Management Methods

Waste Sources/Types	Operation/Equipment Generating Waste	Volume (Estimated total volume during HUCSU phase)	Frequency of Generation	Waste Classification	Proposed Disposal Options	
					Disposal Method	Facility Name
Medical wastes, (dressings, clinical and cleaning materials, blood/body fluid stained dressings needles)	Clinic/LQM	(no estimates available)	Intermittent	Hazardous waste	Offsite disposal as pathogenic waste	FMEnv. accredited facility to handle pathogenic wastes.
Domestic waste (fruits, vegetables, left-over foods, meat and fish cuttings	Kitchen	Kitchen waste= 1000kg per month	Daily	Non-hazardous waste Biodegradable	Maceration & disposal overboard	Standard onsite recommended food macerator
Domestic waste (paper products, wood products, cigarette butts, cotton product)	Kitchen, control room waste LQM	Kitchen waste=10 ton per month office waste=5 ton kg. month	Daily	Non-hazardous waste (Biodegradable)	Offsite disposal	Accredited designated landfill
Domestic waste (plastic wares, PVC pipes, Styrofoam, aluminium foils, drink packs, tetrapacks, nylon, bottles/glass materials, hair	Kitchen, control room waste	Approx. 10 tons per month	Daily	Non-hazardous waste (Biodegradable)	Offsite disposal	Designated landfill

3.9: Project schedule

The schedule of activities planned for the proposed JK drilling campaign project is summarized in Fig 3.5. Execution window for the JK Drilling campaign and maturation of Wells is planned for Q2, 2020.

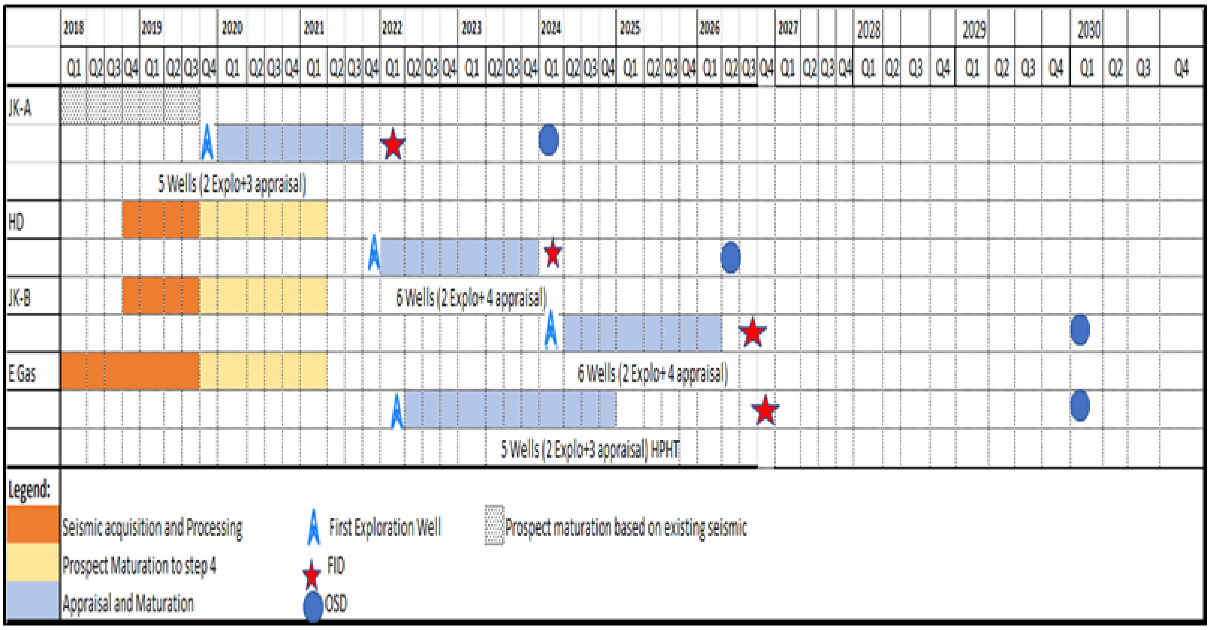

Fig 3.5: Project Implementation Schedule

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, Sediment quality, Surface water quality, Biodiversity, Hydrobiology and fisheries, Social and Health Profile studies of coastal communities. 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.

4.2: Literature Review

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

- Scientific publications.

4.3: Description of Sampling location

The JK Exploration and Appraisal Wells project EIA involved a two season field data gathering exercise conducted from 27th November 2018 through 7th December, 2018 (Dry season) and 8th through 17th September, 2019 (Wet season). The sampling rationale followed detailed protocol for offshore seabed sampling in accordance to international best practices, DPR and FMEnv guidelines. Details of sampling protocols were as follows:

- Air quality and noise measurements were sampled 200m away from the emission sources of the Well locations in the cardinal directions. Controls established outside the project area in the Windward (Upwind) and Downwind (Leeward) directions from the emission sources.
- **Surface water and Sediment quality**: Sampling was conducted in centric circles in the north, south, east and West direction at 200m, 500m, 800m, 1,200m from the proposed Well locations along the direction of most persistent bottom current.
- Control samples points located outside the JK field boundaries in the North, East and West locations to take cognisance of the dominant coastal hydrodynamics (tidal and longshore currents).

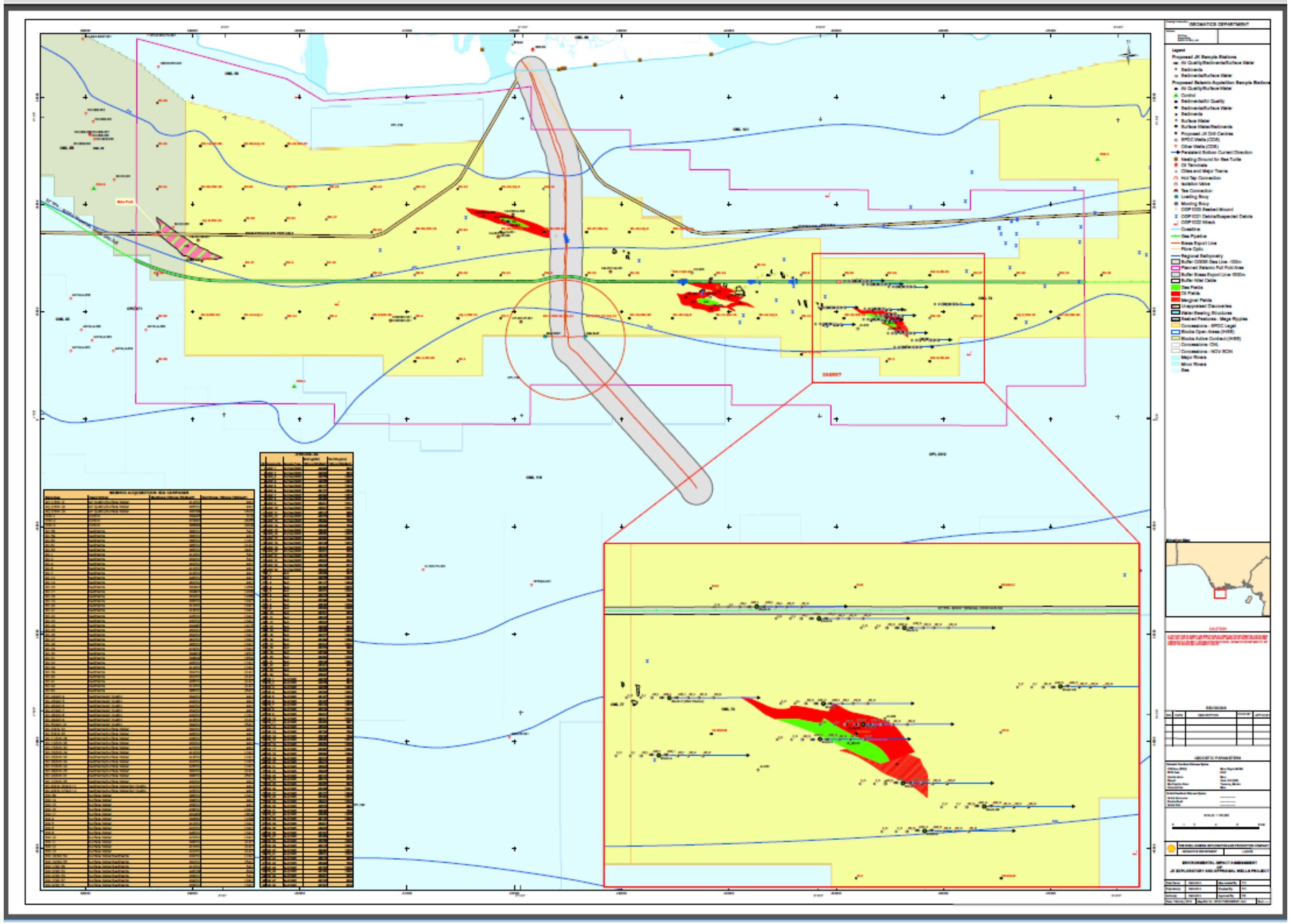

Fig 4.1: Sampling map for the JK Exploration and Appraisal Wells Project

The summary of sampling locations for various environmental spheres around the JK Exploration and Appraisal Wells Project is presented in **Table 4.1a.** Sample profiling of all environmental spheres around the blocks in the JK cluster are presented in Table 4.1b. The details of the coordinates of each environmental component are presented in **Appendix 2.** All samples were analysed at the analytical laboratory of the International Energy Services Limited, Port Harcourt, Rivers State.

Table 4.1a: Quantities of samples to be obtained during the field data gathering

S/N	Environmental component	No. of sampling points	Control Points
1	Ambient Air quality and noise	24	3
2	Surface water quality	72	3
3	Sediment quality	96	3
4	Social Profile	12 communities	-
5	Health Profile	12 communities	-

Table 4.1b: Sampling profiling along the JK field cluster

	Air quality			Surface water quality			Sediment quality		
Block D	200m	200m	500m	800m	1200m	200m	500m	800m	1200m
	ASW6	ASW6	SW5	S3	S15	ASW6	SW5	S3	S15
	ASW5	ASW5	SW6	SW27	SW39	ASW5	SW6	SW27	SW39
Block E	200m	200m	500m	800m	1200m	200m	500m	800m	1200m
	ASW8	ASW8	SW7	S4	S16	ASW8	SW7	S4	S16
	ASW7	ASW7	SW8	SW28	SW40	ASW7	SW8	SW28	SW40
Block H	200m	200m	500m	800m	1200m	200m	500m	800m	1200m
	ASW16	ASW16	SW15	S8	S20	ASW16	SW15	S8	S20
	ASW15	ASW15	SW16	SW32	SW44	ASW15	SW16	SW32	SW44
Block C (mini cluster)	200m	200m	500m	800m	1200m	200m	500m	800m	1200m
	ASW4	ASW4	SW3	S2	S14	ASW4	SW3	S2	S14
	ASW3	ASW3	SW4	SW26	SW38	ASW3	SW4	SW26	SW38
Block F	200m	200m	500m	800m	1200m	200m	500m	800m	1200m
	ASW10	ASW10	SW10	S5	S17	ASW10	SW10	S5	S17
	ASW9	ASW9	SW9	SW29	SW41	ASW9	SW9	SW29	SW41
Block G	200m	200m	500m	800m	1200m	200m	500m	800m	1200m
	ASW12	ASW12	SW11	S6	S18	ASW12	SW11	S6	S18
	ASW11	ASW11	SW12	SW30	SW42	ASW11	SW12	SW30	SW42
Block I	200m	200m	500m	800m	1200m	200m	500m	800m	1200m
	ASW20	ASW20	SW19	S10	S22	ASW20	SW19	S10	S22
	ASW19	ASW19	SW20	SW34	SW46	ASW19	SW20	SW34	SW46
Block A	200m	200m	500m	800m	1200m	200m	500m	800m	1200m
	ASW2	ASW2	SW1	S1	S13	ASW2	SW1	S1	S13
	ASW1	ASW1	SW2	SW25	SW37	ASW1	SW2	SW25	SW37
Block J	200m	200m	500m	800m	1200m	200m	500m	800m	1200m
	ASW22	ASW22	SW21	S11	S23	ASW22	SW21	S11	S23

	Air quality			Surface water quality			Sediment quality		
	ASW21	ASW21	SW22	SW35	SW47	ASW21	SW22	SW35	SW47
Block GS	200m	200m	500m	800m	1200m	200m	500m	800m	1200m
	ASW14	ASW14	SW13	S7	S19	ASW14	SW13	S7	S19
	ASW13	ASW13	SW14	SW31	SW43	ASW13	SW14	SW31	SW43
Block K	200m	200m	500m	800m	1200m	200m	500m	800m	1200m
	ASW24	ASW24	SW24	S12	S24	ASW24	SW24	S12	S24
	ASW23	ASW23	SW23	SW36	SW48	ASW23	SW23	SW36	SW48
Block HE	200m	200m	500m	800m	1200m	200m	500m	800m	1200m
	ASW18	ASW18	SW18	S9	S21	ASW18	SW18	S9	S21
	ASW17	ASW17	SW17	SW33	SW45	ASW17	SW17	SW33	SW45

4.4: Sampling methodology

Table 4.1c gives a summary of the methods/instruments used for sampling various environmental spheres as approved in the Terms of Reference (ToR).

Table 4.1c: 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_2S. 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
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: Quality Assurance and 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 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 H_2SO_4, HNO_3, $Na_2S_2SO_3$ Winkler's (A and B), and Starch Indicator were used for all the batches of samples to ensure comparability and reliability of results.

4.6: Statistical Analyses

Data for air, noise, water and sediment qualities were summarized using measures of central tendency (mean) and dispersion (standard deviation) to even-out potential errors in field data resulting from the instrument and those introduced by the observer. The parametric Single Factor Analysis of Variance (ANOVA) was used to test for significant differences in the measured parameters at specified distances (200m, 500 m, 800m and 1200 m) from the Well locations and the control stations. Where significant differences ($P<0.05$) were detected, the *a posteriori* Duncan Multiple Range (DMR) test was used to locate the source(s) of difference(s). Where serious disparities in sample sizes failed to meet the assumptions underlying the use of ANOVA, the non-parametric Chi-square goodness of fit test to ratio 1:1 was used to test for significant differences between the mean values for all treatments being compared. All statistical analyses were executed using SPSS version 20.0 and Excel Statistical ToolPak. The diversity of the biotic communities (phytoplankton, zooplankton and macrobenthos) was computed using 'PAST' computer based programme for ecological statistics. The Shannon diversity values at the different distances from the Facilities were compared.

4.7: Meteorology and Air Quality

4.7.1: Climate and Meteorology

The study area is located in the Gulf of Guinea with its climate being influenced by the Atlantic Ocean characterized with dry and wet seasons associated with the movement of the Inter-Tropical Convergence Zone (ITCZ) north and south of the equator. The dry season which usually occurs from November to March is characterized by the northeast trade winds while the wet season which typically occurs from April to October is dominated by the Southwest monsoon. Ten-year meteorological information on Port Harcourt obtained from the Nigerian Meteorological Agency, NIMET was utilized for the climatic description of the area. The JK field is within the same climatic zone as Port Harcourt. Within the Project area, rain falls throughout the year peaking between June and September. The mean annual rainfall as measured in Port Harcourt, was 2,874 mm. The prevalent wind direction is the South-westerly/Southerly which dominates the rainy season with speeds ranging from 0.4 to 5 m/s. In the dry season, wind speeds range between 0.3 – 2 m/s.

Daily temperatures in the area are characteristically high ranging between 27 ^{o}C to 32 ^{o}C in the wet season and 32 ^{o}C and 33 ^{o}C in the dry season. The relative humidity is usually above 80% in the rainy season, and may decrease to below 50% in the dry season while the atmospheric pressure varies diurnally ranging between 1010 mB in the dry season and 1014 mB in the wet season.

Rainfall

The mean monthly rainfall in the study is presented in Figure 4.7.1. Rainfall ranges between 10 and 430 mm with annual rainfall exceeding 3000 mm. Lowest annual rainfall is observed from November to January increasing thereafter gradually from February to June when it experiences the first peak followed by the second peak in September.

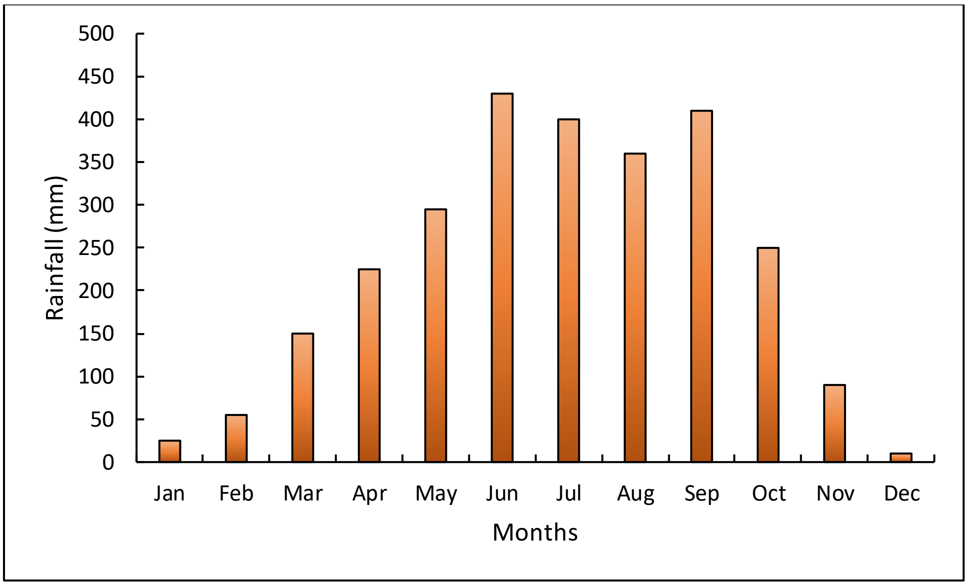

Fig. 4.7.1: Mean Rainfall Distribution in the Study Area (NIMET, 2018)

Relative humidity and Ambient Air temperature

The trend in relative humidity in study area is presented in Figure 4.7.2. The relative humidity ranges from 58 to 81% reaching its peak in the rainy season between June and September. The mean monthly minimum air temperature ranged from 22 to 24.25 °C while the mean maximum temperature ranged from 27 to 32.8 °C during the period (2008 – 2018) (Figure 4.7.3).

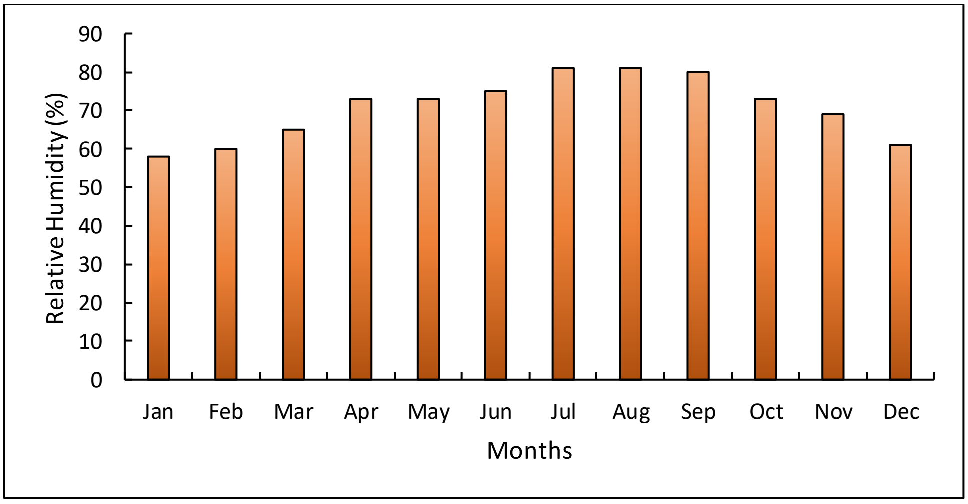

Fig. 4.7.2: Mean Relative Humidity Distribution (NIMET, 2018)

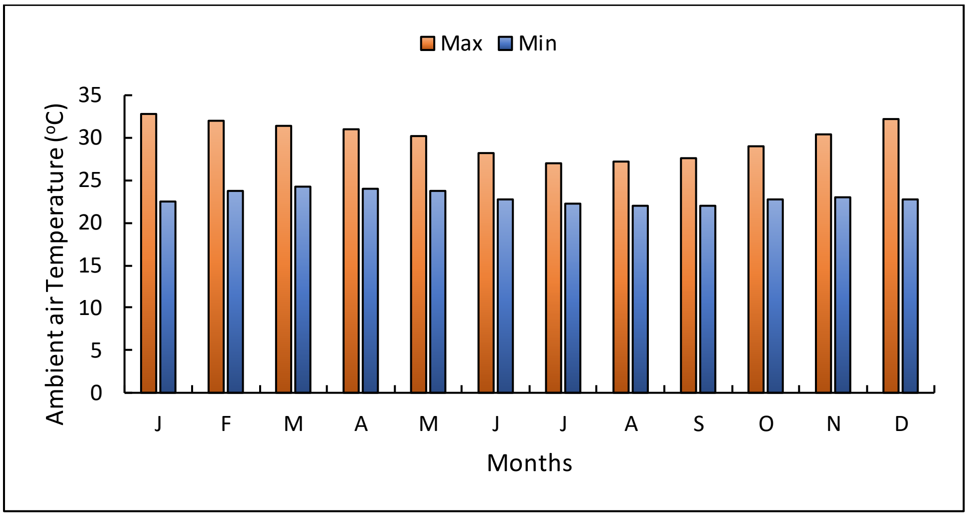

Fig. 4.7.3: Mean Air Temperature Distribution (NIMET, 2018)

Wind Pattern

Within the study area, surface wind is characterized by small diurnal variations influenced by sea breezes which reaches maximum level during the night due to radiation cooling leading to instability in the surface layer. The winds vary from gentle breeze (0.4 - 1.4 m/sec) to light breeze (1.6 - 3.3 m/sec) and moderate breeze (5.5 - 7.9 m/sec). Winds above 10 m/sec are rare and occur only during thunderstorms. Figure 4.1d shows the typical wind rose diagram for the study area. The prevalent wind direction is the South-westerly, Westerly and Southerly.

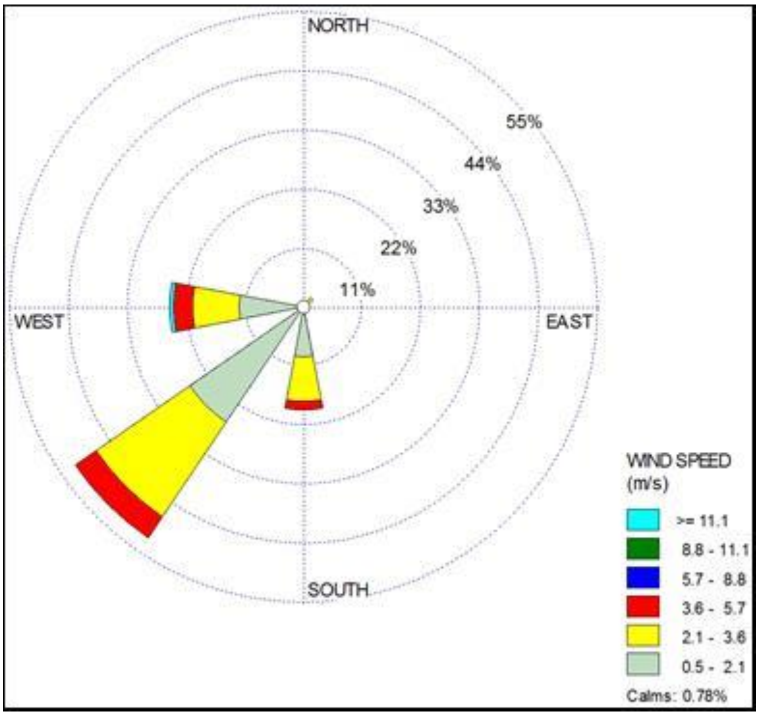

Fig. 4.7.4: Wind Speed and Prevailing Direction in the Study Area (NIMET, 2018)

Micro-Climatic data

The summary results of field sampling for microclimatic data is presented in Table 4.7.1 Detailed results are presented in Appendix 8.0. Ambient air temperature ranged from 26.1 to 35.7°C with no significant difference between the project locations and control. Temperatures at the project locations were significantly higher during the dry than wet season (P<0.05) as is expected in the area.

Relative humidity ranged from 9.1% to 92% with no significant difference between project locations and control. Significantly higher humidity occurred during the wet season compared to dry season (P<0.05) which is normal for the area. Atmospheric pressure ranged from 1003 to 1015 pa during the study with no significant difference between project locations and control but levels were significantly higher during the wet than dry season (P<0.05).

Average wind speed recorded during sampling period ranged from 0.3 to 6.2 m/s (Figure 4.7.5 and 4.7.6) with the peak wind direction being SW during the wet and NE during the dry season (Figure 4.7.7 and 4.7.8). There was no significant difference in wind speeds between project location and control but levels were significantly higher during wet season then dry season (P<0.05). Highest winds were measured in Block J while the lowest occurred in Block HE during the wet season. All measured wind levels were within light to moderate breeze.

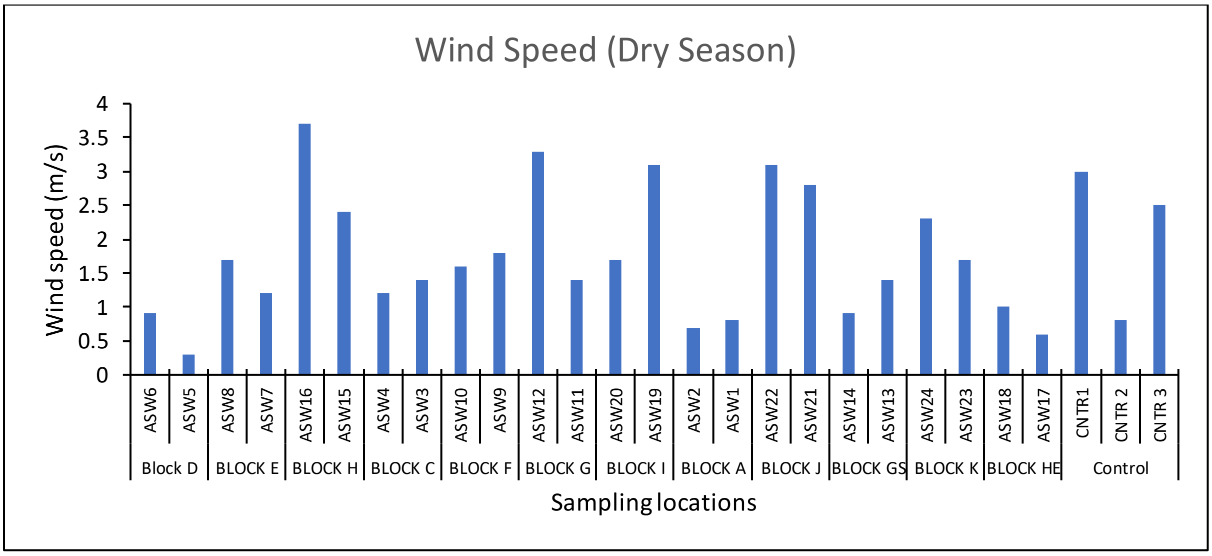

Fig. 4.7.5: Mesured wind speeds in the project and control areas during the dry season.

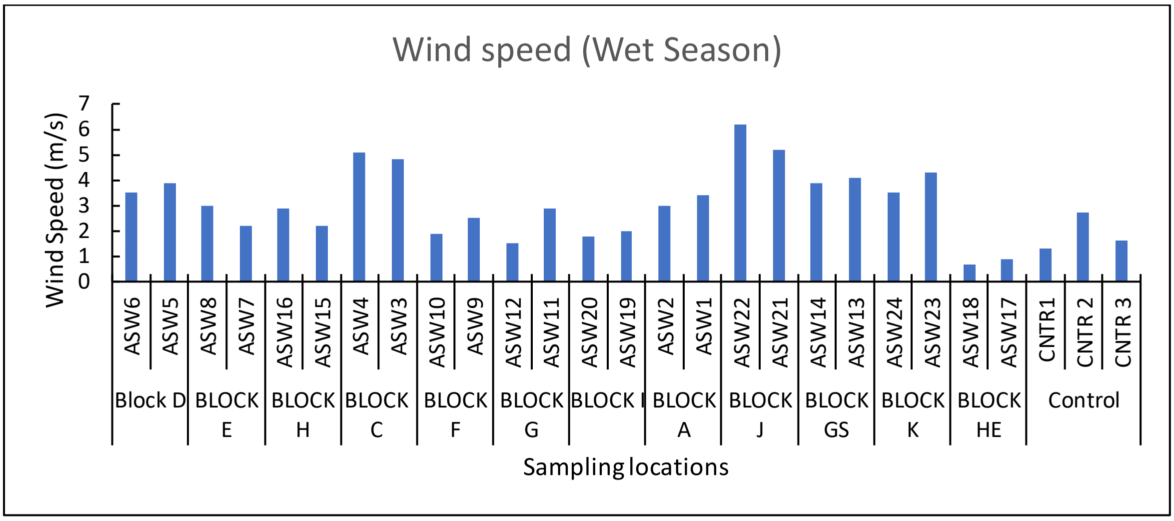

Fig. 4.7.6: Mesured wind speeds in the project and control areas during the wet season.

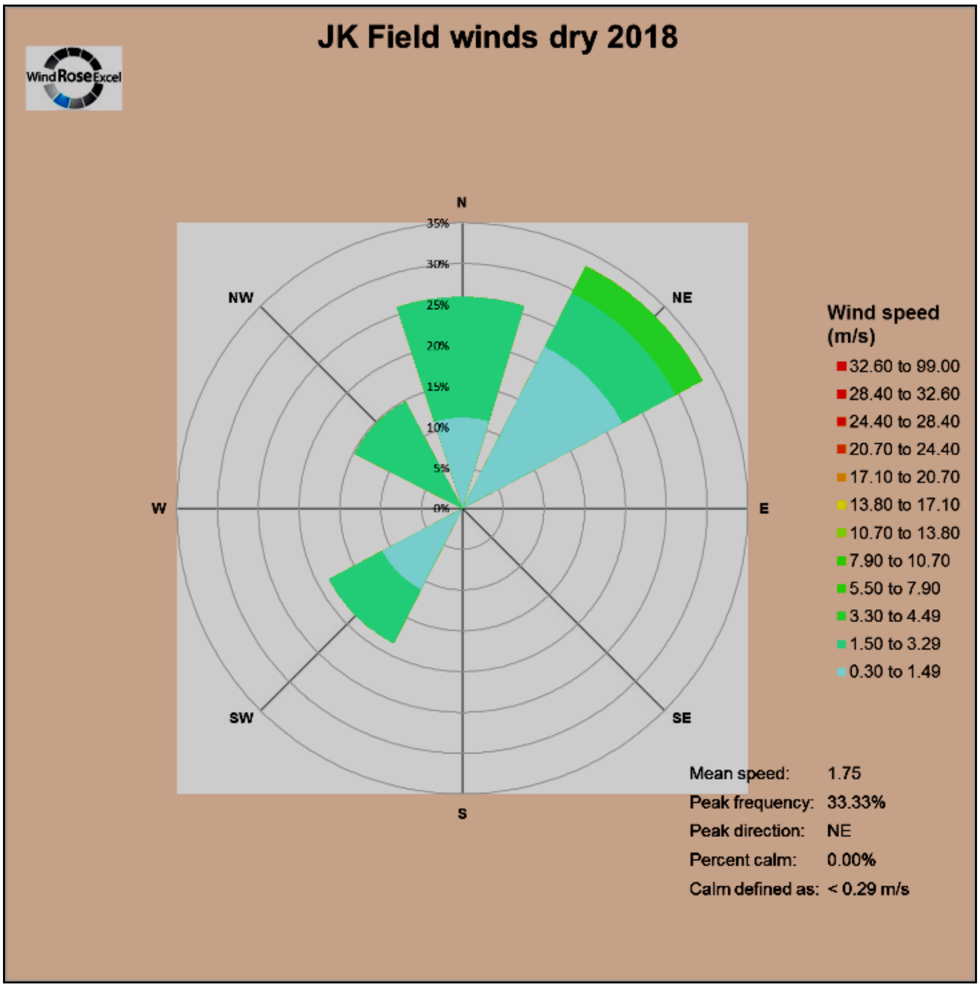

Fig. 4.7.7: Wind rose diagram for the JK field during the dry season.

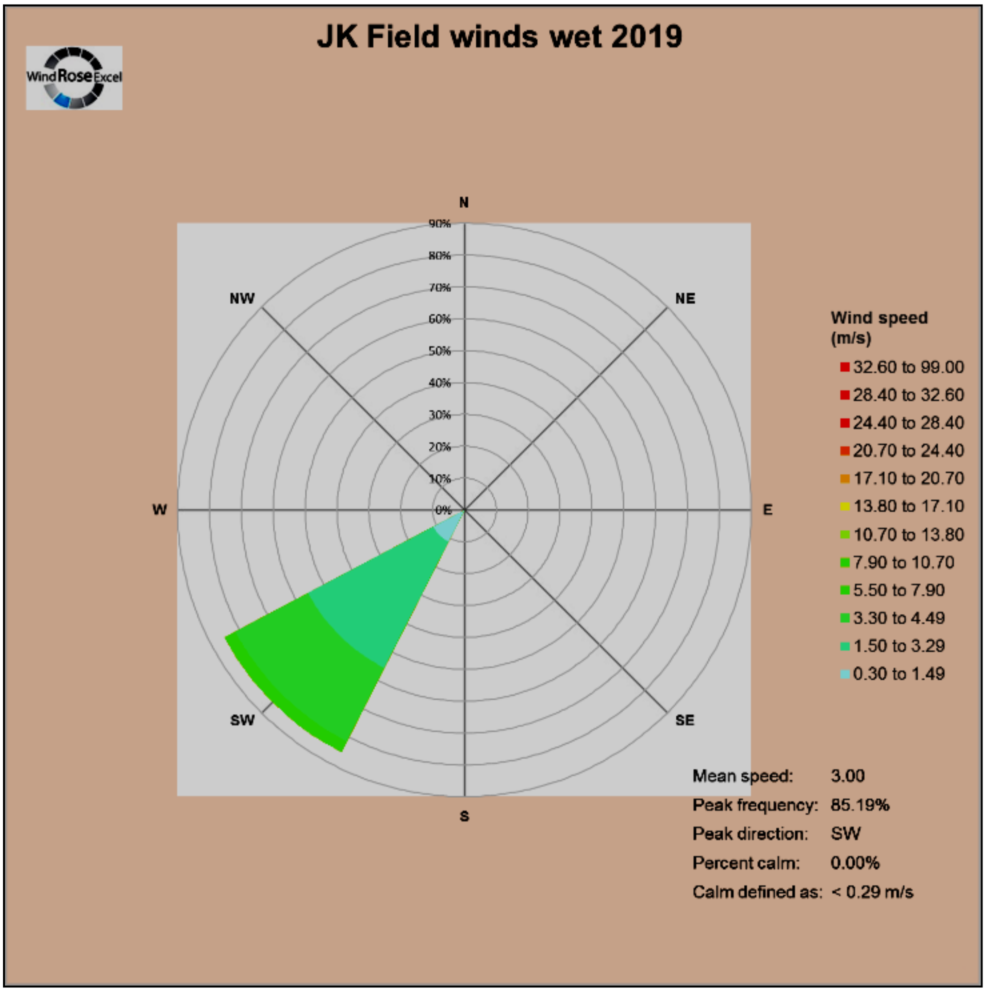

Fig. 4.7.8: Wind rose diagram for the JK field during the wet season.

Table 4.7.1: Summary of Results of Microclimatic data in the JK field area

Parameters	**Dry Season**				**ANOVA P Study area vs Control**	**Wet Season**				**ANOVA P Study area vs Control**	**ANOVA P Dry vs Wet**
	Project Area										
	Range	Mean	Range	Mean		Range	Mean	Range	Mean		
Ambient Temperature (^{O}C)	27.2-35.7	32.5±2.2	30.5-32.6	31.7±0.9	0.486	26.1-35.7	29.3±2.5	27-30.8	29.2±1.6	0.975	0.000*
Relative Humidity (%)	58.7-84.4	69.7±7.9	68.3-75.3	71.0±3.1	0.719	9.1-92	77.08±16.42	74-87.5	79.23±5.91	0.830	0,046
Atm. Pressure (Pa)	1003-1008	1005.3±1.8	1005-1008	1006.7±1.2	0.244	1007-1015	1011±1.91	1010-1013	1011±1.41	0.123	0.000*
Wind Speed (m/s)	0.3-3.7	1.7±0.9	0.8-3	2.1±0.9	0.509	0.7-6.2	3.14±1.36	1.3-2.7	1.87±0.60	0.136	0.000*
Wind Direction	NE, N, NW, SW		SW	SW			SW		SW	N/A	

Source: JK Field EIA Fieldwork

4.7.2: Air Quality and Noise

The measured gaseous pollutants in JK Field Development area as obtained during the fieldwork are summarized in Table 4.7.2. Detailed results are presented in Appendix 8.0. Sulphur oxides (SOx), Carbon oxides (COx), Hydrogen sulphide (H_2S), Volatile hydrocarbons (CxHy), ammonia (NH_3) and ozone (O_3) were not detected during the field study. Nitrogen oxides (NOx) were only detectable during the dry season at the project area only.

Suspended Particulate Matter (SPM) ranged from 19 to 50 µg/m^3 with no significant difference between project locations and control but levels were significantly higher during the dry than wet season ($P<0.05$) which may be attributed to wash out by rain during the wet season. All concentrations were however well within the National ambient air quality limits (Table 4.7.2).

Nitrogen Dioxide was only detected during the dry season in the project area and ranged from below detection limit to 9.9 µg/m^3 which is within the National ambient air quality limits (Figure 4.7.2). In general, the air shed within the project area was not polluted at the time of study.

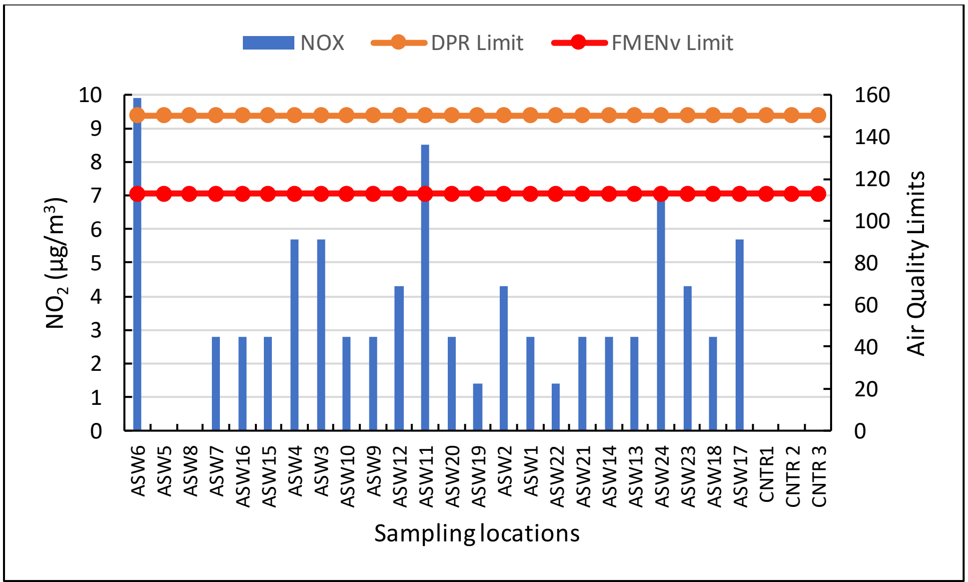

Figure 4.7.2: Measured levels of Nitrogen dioxide in the study area compared to National Limits.

Noise: Measured noise levels ranged from 72.4 to 79.8 (dBA) during the study with no significant difference between project area and control and between the seasons. All measured noise levels were within the National regulatory 8 Hour limit of 90 dBA.

Table 4.7.2: Summary of Results of Air Quality and Noise measurements in the JK field area

Parameters	Dry season				ANOVA P Study area vs control	Wet season				ANOVA P Study area vs control	ANOVA P Dry season vs Wet season	FMENv Limits	DPR Limits
	Project Area		Control			Project Area		Control					
	Range	Mean	Range	Mean		Range	Mean	Range	Mean				
SO_X (μg/m^3)	<19.9-<19.9	<19.9±0	<19.9-<19.9	<19.9±0	N/A	<19.9-<19.9	<19.9±0	<19.9-<19.9	<19.9±0	N/A	N/A	26* 26**	100-150*
NO_X (μg/m^3)	<1.42-9.9	4.11±2.20	<1.42-<1.42	<1.42±0	N/A	<1.42-<1.42	<1.42±0	<1.42-<1.42	<1.42±0	N/A	N/A	75-113*	150*
CO_X (μg/m^3)	<8.7-<8.7	<8.7±0	<8.7-<8.7	<8.7±0	N/A	<8.7-<8.7	<8.7±0	<8.7-<8.7	<8.7±0	N/A	N/A		
H_2S (μg/m^3)	<1.1-<1.1	<1.1±0	<1.1-<1.1	<1.1±0	N/A	<1.1-<1.1	<1.1±0	<1.1-<1.1	<1.1±0	N/A	N/A		
C_XH_Y (ppm)	<1.0-<1.0	<1.0±	<1.0-<1.0	<1.0±0	N/A	<1.0-<1.0	<1.0±0	<1.0-<1.0	<1.0±0	N/A	N/A	160*	
SPM10 (μg/m^3)	19-50	31.1±9.9	30-32	31.3±0.9	0.927	10-31	20.21±6.05	18-26	22.33±3.30	0.331	0.000*	250* 600**	60-90*
Noise Level (dBA)	74.3-78.4	75.9±1.0	73.4-77.9	75.5±1.8	0.378	72.4-79.8	75.37±1.78	73.5-76.8	74.67±1.51	0.399	0.159	90	90

Source: Fieldwork

4.8: Water Quality Studies

The summary results of water quality studies in the JK field is presented in Table 4.8.1. Detailed results of surface water quality are shown Appendix 8.0.

Surface Water Physicochemistry

Temperature, pH, Electrical Conductivity, Alkalinity: Temperature ranged from 26.1 to 32°C in the project area and from 27.5 to 29.1°C at the controls. There were no significant differences between project area and control but values in the dry season were significantly higher than those of the wet season. All values were normal for tropical coastal waters. Water temperatures in tropical ocean waters are typically above 25°C depending on season (Wiesenburg, 1988) reaching a maximum at above 30°C. The hydrogen ion concentration (pH) ranged from 8.07 to 8.65 at the project area and from 8.24 to 8.57 at the controls with no significant differences between project location and control but dry season values were significantly higher than those of the wet season (Figure 4.8.1 and 4.8.2). The values of pH are normal for natural marine waters. According to CWT (2004), the pH of seawater is usually between 7.5 and 8.4. Similarly, Wetzel (1983) reports that the pH of marine waters is similar to that of estuarine waters and is usually stable between 7.5 and 8.5 worldwide. Lethal effects of pH on aquatic life occur below pH 4.5 and above pH 9.5 (Researchgate, 2017a). Alken Murray Corp (2006) gives the acceptable pH range for most finfish and shellfish species as 6.8-8.5.

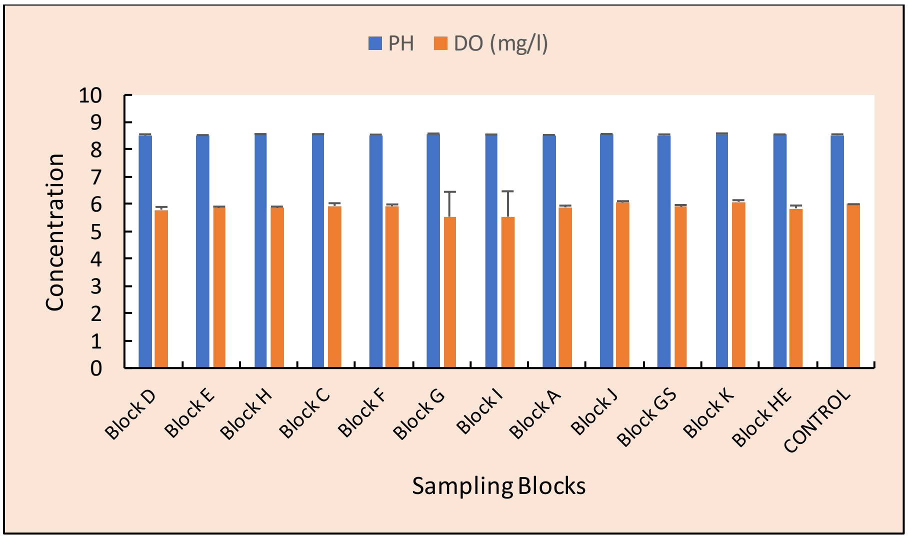

Figure 4.8.1: Levels of pH in study area compared with control during the dry season

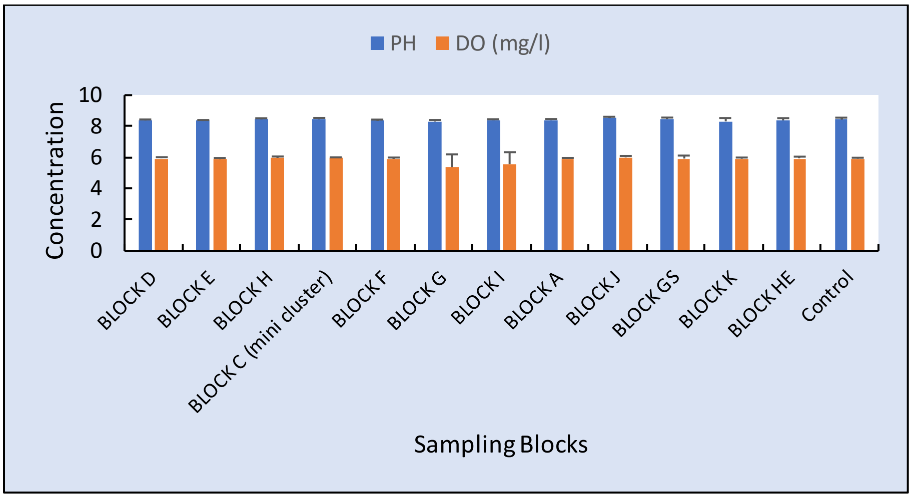

Figure 4.8.2: Levels of pH in study area compared with control during the wet season

Electrical conductivity, TDS and Chloride are all measures of the salinity (salt content) of sea water. Electrical conductivity ranged from 27150 to 47000 µS/cm at the project locations and from 38300 to 42100 µS/cm at the controls. Values were significantly higher in the dry than wet season but project locations were not significantly different from controls (Figure 4.8.3 and 4.8.4). Observed conductivity values are within background levels for the Niger Delta waters (RPI, 1985) and normal values for tropical coastal waters. The natural EC of freshwaters usually lie between 50 and 1500 µS/cm while estuaries and coastal waters have much higher values (typically from 20,000 to 40,000 µS/cm) with levels increasing as salinity increases (NSW, 2010). According to NSW (2010), electrical conductivity in the range of 15,000-48,000 µS/cm is typical of natural brackish waters (Estuary and Near-coast waters).

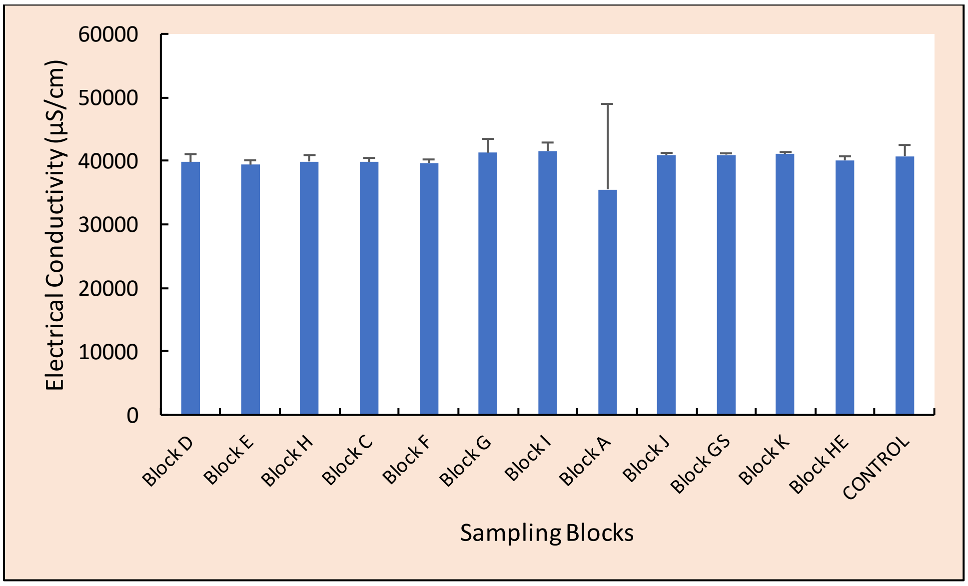

Figure 4.8.3: Electrical conductivity levels in the study area compared with control during the dry season

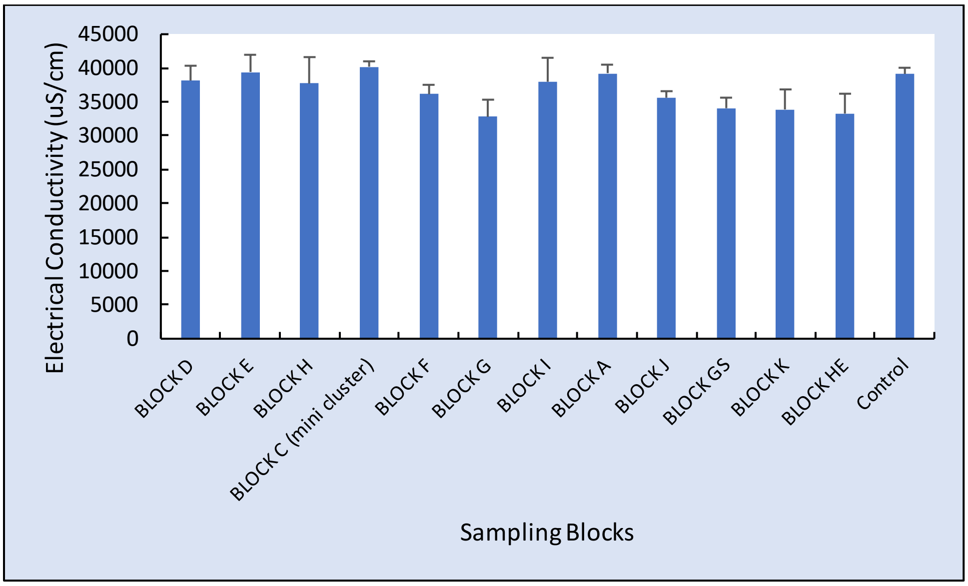

Figure 4.8.4: Electrical conductivity levels in the study area compared with control during the wet season

Alkalinity ranged from 8 to 33 mg/l at study locations and from 8-16 mg/l at controls with no significant differences between study location and control but significantly higher values were observed during the dry season at project locations. Alkalinity is the measurement of the water's ability to neutralize acids. It represents the buffering capacity of water and its ability to resist a change in pH. According to USEPA (2006) fresh waters can have alkalinity of 30-90 mg/l depending on watershed, while that of seawater averages 116 mg/l with those of brackish water in-between. According to Kentucky Water Watch (2016) the buffering capacity should be at least 20 mg/l for protection of aquatic life with the acceptable range for most finfish being 20-200 mg/1. Compared with recommended limits, the observed alkalinity values in the area are quite low and well below expected range for such coastal marine waters.

Table 4.8.1: Summary of surface water physicochemical and microbiological measurements in the JK field and control locations

Parameters	Dry season surface water				ANOVA P Values dry vs control	Wet season surface water				Anova P wet vs control	ANOVA P Values Dry vs Wet	Limits/ Normal Values
	Project Area		Control			Project area		Control				
	Range	Mean±SD	Range	Mean±SD		Range	Mean±SD	Range	Mean±SD			
TEMP (^oC)	26.3-32	28.7±0.9	28.3-29.1	28.7±0.3	.945	26.1-29.4	27.5±0.7	27.5-28.1	27.9±0.3	.296	.000	
PH	8.46-8.59	8.54±0.03	8.51-8.57	8.53±0.03	.438	8.07-8.65	8.39±0.12	8.24-8.52	8.42±0.13	.631	.000	3.1-8.6 [i] 6.5-8.5 [ii]
EC (µS/cm)	40300-47000	40060±4207	38300-42100	40767±1746.1	.775	27150-43500	36418±3523	38300-40400	39133±910	.189	.000	10-42100 [i] >1500-48,000 [iii]
TURB (NTU)	0-0	0±0	0-0	0±0		0-0	0±0	0-0.3	0.1±0.14			
DO (mg/l)	3.4-6.2	5.84±0.45	6-6	6±0	.549	3.7-6.2	5.83±0.43	5.9-6	5.93±0.05	.691	.925	2-9.0 [i] >5.0 [v]
TDS (mg/l)	24660-32920	28307±952	26813-29470	28537.7±1221	.686	13580-34640	25176±3353	27090-36810	30657±4369	.007	.000	2.0-35350 [i]
Cl^- (mg/l)	11502-16972	14487±669	13831-15203	14721.7±630.5	.553	11019-17409	14625±1395	15307-16046	15610±316	.229	.281	
Alkalinity (mg/l)	8-16	13.64±2.12	8-16	12±3.3	.204	8-33	12.34±3.36	8-16	13.33±3.77	.621	.002	>20 [v]
Colour (Pt-Co)	0-0.02	0±0	0.01-0.01	0.01±0		0-0.02	0±0	0-0.01	0±0			
TSS (mg/l)	16-36	21.78±3.49	20-22	21.33±0.94	.827	10-34	21.35±3.17	20-22	21.33±0.94	.992	.358	<80 [v]
COD (mg/l)	149-205	173.63±10.24	179-199	188±8.29	.019	154-200	172.55±8.48	182-201	190.33±7.93	.001	.672	1.9-2460 [i] <20 [vi]
BOD (mg/l)	0.1-1.3	0.66±0.27	0.5-0.9	0.67±0.17	.946	0.3-3.4	0.99±0.48	0.8-1.3	1.03±0.21	.875	.000	<3 [vi]
NO_3^- (mg/l)	0.2-1.9	0.97±0.4	0.9-1.2	1±0.14	.889	0.4-3.4	1.29±0.5	0.6-0.9	0.8±0.14	.101	.000	<22 [vi]
NO_2^- (mg/l)	0.68-5.93	3.16±1.29	2.96-3.94	3.29±0.46	.870	0.29-2.51	0.97±0.38	0.48-0.59	0.53±0.05	.052	.000	<3.3 [vi]
SO_4^{2-} (mg/l)	580-925	761.91±79.6	687-789	730±43.15	.495	840-1860	1547±167	1380-1500	1441±49	.279	.000	
PO_4^{3-} (mg/l)	0.11-0.95	0.4±0.16	0.41-0.42	0.42±0	.848	0.18-2.9	0.99±0.45	0.83-1.2	0.96±0.17	.900	.000	<0.02 [vi]
NH_4^+ (mg/l)	0.09-1.46	0.47±0.21	0.43-0.56	0.47±0.06	.961	0.18-1.58	0.6±0.23	0.28-0.37	0.31±0.04	.036	.000	<0.3 [vi]

Parameters	Dry season surface water				ANOVA P Values dry vs control	Wet season surface water				Anova P wet vs control	ANOVA P Values Dry vs Wet	Limits/ Normal Values
	Project Area		Control			Project area		Control				
	Range	Mean±SD	Range	Mean±SD		Range	Mean±SD	Range	Mean±SD			
O/G (mg/l)	0-0	0±0	<0.001-<0.001	<0.001±0		0-0	0±0	0-0	0±0			
THC (mg/l)	0-0	0±0	<0.001-<0.001	<0.001±0		0-0	0±0	0-0	0±0			
TPH (mg/l)	0-0	0±0	<0.001-<0.001	<0.001±0		0-0	0±0	0-0	0±0			<1.0[viii]
PAH (mg/l)	0-0	0±0	<0.001-<0.001	<0.001±0		0-0	0±0	0-0	0±0			
BTEX (mg/l)	0-0	0±0	<0.001-<0.001	<0.001±0		0-0	0±0	0-0	0±0			<0.1[viii]
Ni (mg/l)	0.012-1.099	0.269±0.198	0.133-0.974	0.624±0.357	.004	0.028-0.491	0.192±0.086	0.125-0.258	0.185±0.055	.921	.000	BDL-0.52 [i] 0.5 [vii]
Fe (mg/l)	0.018-0.186	0.077±0.033	0.014-0.437	0.158±0.197	.004	0.014-0.443	0.09±0.074	0.122-0.137	0.129±0.006	.367	.093	BDL-4.75 [i] 3.0 [vii]
Pb (mg/l)	0.03-0.545	0.328±0.084	0.094-0.289	0.192±0.097	.005	0.002-0.853	0.273±0.13	0.102-0.138	0.12±0.018	.030	.002	BDL-0.66 [i] 0.5 [vii]
Cu (mg/l)	0.011-0.136	0.045±0.024	0.022-0.029	0.025±0.003	.177	0.011-0.67	0.041±0.06	0.022-0.039	0.03±0.007	.782	.536	0.50 [vii]
Cr (mg/l)	0.005-0.399	0.137±0.099	0.166-0.172	0.169±0.003	.768	0.011-0.315	0.118±0.078	0.105-0.136	0.121±0.016	.618	.041	0.50 [vii]
Zn (mg/l)	0.001-0.234	0.047±0.038	0.008-0.038	0.019±0.014	.304	0.003-0.139	0.043±0.032	0.016-0.018	0.017±0.001	.197	.838	50 [vii]
Cd (mg/l)	0.005-0.153	0.049±0.024	0.009-0.018	0.014±0.005	.005	0.004-0.14	0.038±0.025	0.005-0.011	0.009±0.003	.081	.000	0.005 [vii]
Mn (mg/l)	0.011-0.111	0.049±0.024	0.051-0.122	0.083±0.029	.019	0.004-0.127	0.037±0.02	0.035-0.047	0.039±0.006	.823	.008	
Ba (mg/l)	<0.01	<0.01	<0.01	<0.01		<0.01	<0.01	<0.01	<0.01			
Co (mg/l)	<0.01	<0.01	<0.01	<0.01		<0.01	<0.01	<0.01	<0.01			
Hg (mg/l)	<0.01	<0.01	<0.01	<0.01		<0.01	<0.01	<0.01	<0.01			0.0005 [vii]
V (mg/l)	<0.01	<0.01	<0.01	<0.01		<0.01	<0.01	<0.01	<0.01			BDL-1.56 [i]
K (mg/l)	325-392	367.45±16.56	376.6-390.4	382±6	.128	301-396	353±19	353-372	363±8	.382	.000	
Na (mg/l)	9078-10448	9981±257	9563-9948	9791±165	.212	1021-10301	9936±898	9892-9963	9939±33	.995	.625	
Mg (mg/l)	1023-10051	1307±881	1124-1243	1171±52	.791	1009-10062	1270±879	1184-1224	1201±17	.893	.749	

Parameters	Dry season surface water				ANOVA P Values dry vs control	Wet season surface water				Anova P wet vs control	ANOVA P Values Dry vs Wet	Limits/ Normal Values
	Project Area		Control			Project area		Control				
	Range	Mean±SD	Range	Mean±SD		Range	Mean±SD	Range	Mean±SD			
Ca (mg/l)	385-428	411±8	400-408	405±3	.185	309-459	397±40	401-406	404±2	.780	.001	
HUF (cfu/ml)	0-0	0±0	NIL-NIL	NIL±NIL		0-0	0±0	0-0	0±0			
HUB (cfu/ml)	2-2	2±0	NIL-NIL	NIL±NIL		0-0	0±0	0-0	0±0			
THB (cfu/ml) x 10^2	1.68-2.41	2.09±0.18	2.13-2.37	2.23±0.1	.397	0.17-2.71	1.89±0.37	1.63-2.11	1.8±0.22	.645	.237	
THF (cfu/ml) x 10^2	1.01-9.8	1.34±0.89	1.02-1.11	1.05±0.04	.584	0.01-1.52	0.68±0.51	0.07-1.1	0.41±0.49	.376	.000	
SRB (cfu/ml) x 10^3	0.9-1.27	1.11±0.11	NA-NA	NA±NA	.667	1.03-1.94	1.41±0.19	1.33-1.5	1.43±0.07	.822	.000	
Coliform (MPN/100 ml)	0-4	0.4±0.83	0-0	0±0		0-0	0±0	0-0	0±0			10000[vii]
[i] (RPI, 1985), [ii] (CWT, 2004), [iii] (NSW,2010), [iv] (Kentucky Water Watch, 2016), [v] (USEPA, 1973), [vi] (Chapman, 1996), [vii] (FAO, 2017), [viii] (Alken Muray, 2006)												

Source: JK field EIA field work

Colour, Turbidity, TSS: Colour, turbidity and total suspended solids (TSS) in water are measures of water's transparency (Bellingham, 1991). Turbidity and colour were below detection limit of measurement indicating relatively clear waters. Water colour can naturally range from 0-300 mg/l Pt-Co with higher values being associated with swamps and bogs due mainly to the presence of complex organic molecules such as humic acids (Researchgate, 2017a). Chapman (1996) reports that normal values of turbidity can range from 1 to 1,000 NTU and levels can be increased by the presence of organic matter pollution, other effluents, or run-off with a high suspended matter content. Total suspended solids were low ranging from 10 to 36 mg/l at the study locations and from 20 to 22 mg/l at the controls (Figure 4.8.5 and 4.8.6). There were no significant seasonal differences in TSS and study locations were also not significantly different from controls. The USEPA guidelines on suspended solids for the protection of fisheries resources recommends values below 80 mg/l for good to moderate fisheries with levels below 25 mg/l providing the highest level of protection for fisheries.

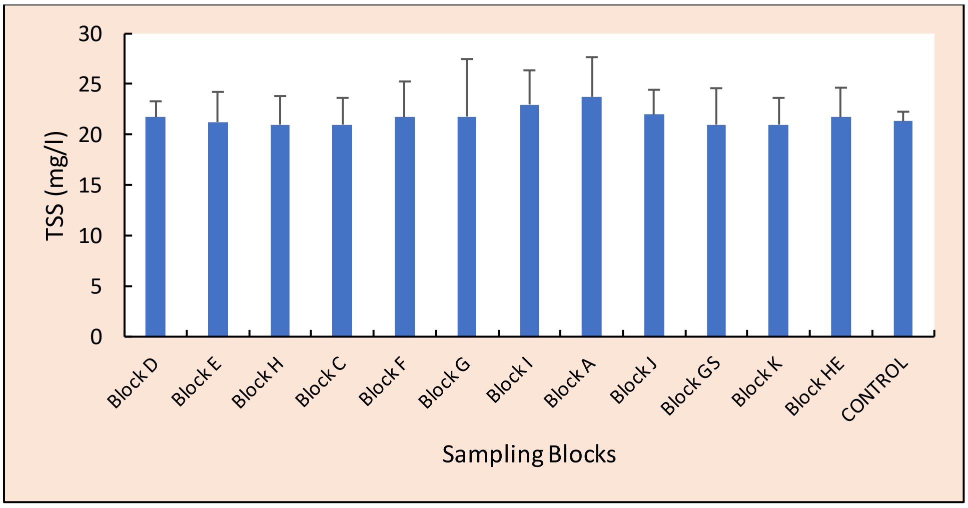

Figure 4.8.5: TSS levels in the study area compared with control during the dry season

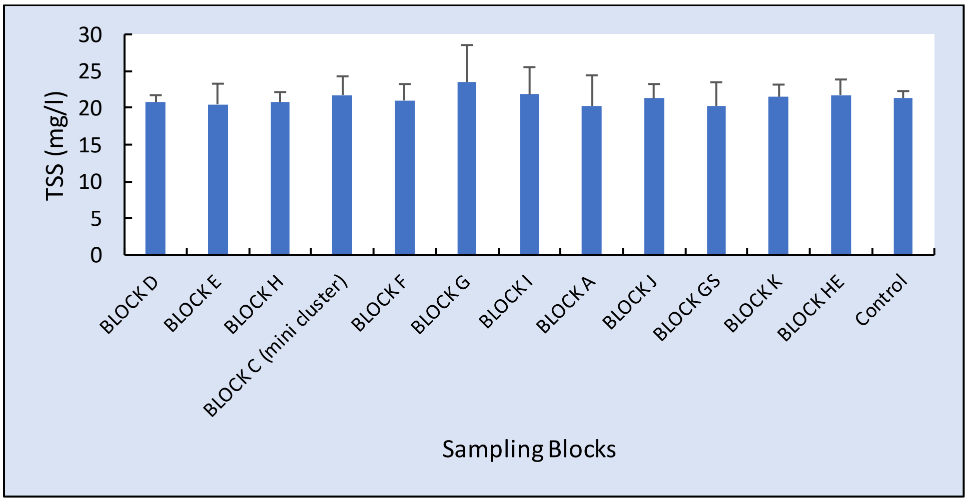

Figure 4.8.6: TSS levels in the study area compared with control during the wet season

Dissolved Oxygen (DO), Chemical Oxygen Demand (COD), Biochemical Oxygen Demand (BOD): Dissolved oxygen ranged from 3.4 to 6.2 mg/l at the study locations and from 5.9 to 6.0 mg/l at the controls. There were no significant seasonal or spatial variations between study locations and control (Figure 4.8.7 and 4.8.8). According to Chapman (1996), DO concentrations below 5 mg/l may adversely affect the functioning and survival of biological communities while levels below 2 mg/l may lead to the death of most fish. Average DO values in the study area and control were generally above 5 mg/l.

Chemical Oxygen Demand ranged from 149 to 205 mg/l at the study locations and from 179 to 201 mg/l at the controls. There was no significant seasonal difference in COD but control locations had significantly higher values during both seasons (Figure 4.3.7 and 4.3.8). According to Chapman (1996) concentrations of COD observed in surface waters range from 20 mg/l or less in unpolluted waters to greater than 200 mg/l in waters receiving effluents. However, all COD concentration observed are considered normal for the Niger Delta Coastal waters. RPI (1985) reported background levels of 1.9 to 2490 mg/l for the Niger Delta waters.

Biochemical Oxygen Demand ranged from 0.1 to 3.4 mg/l in the study locations and from 0.5 to 1.3 mg/l at the control locations. Differences between study locations and control were not significant but seasonal differences were significant ($P<0.05$) with higher values obtained during the wet season possibly linked to riverine discharge from coastal settlements and swamp lands. Natural water typically has a BOD from 0.8 to 5 mg/l (Alken Muray, 2006) showing absence of organic pollution in the waters.

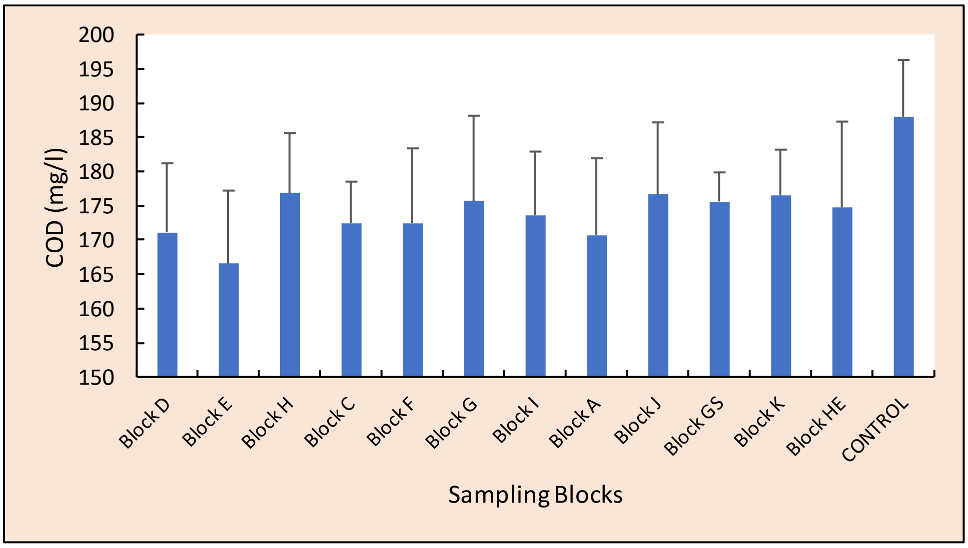

Figure 4.8.7: COD levels in the study area compared with control during the dry season

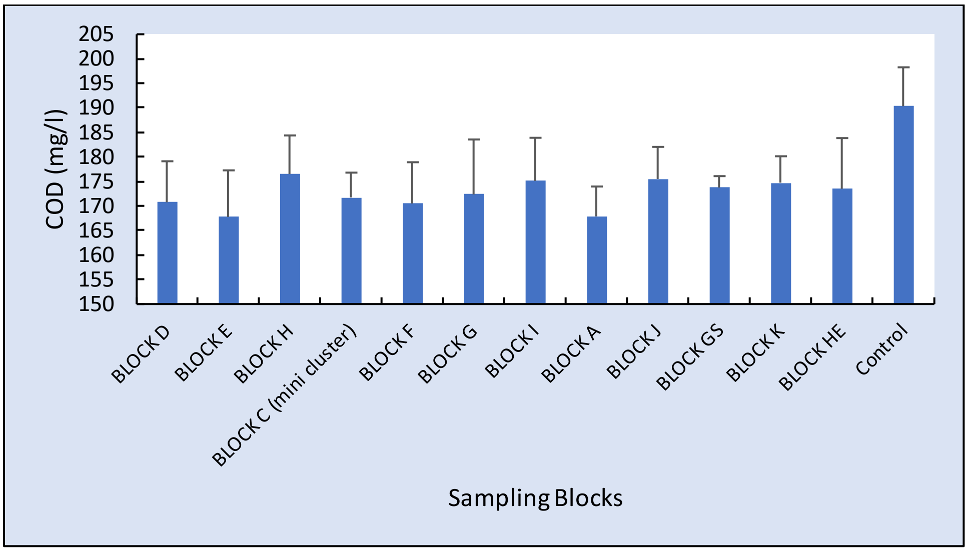

Figure 4.8.8: COD levels in the study area compared with control during the wet season

Nutrients-Nitrate, Nitrite, Ammonium, Phosphate, Sulphate: Nitrate range from 0.2 to 3.4 mg/l at the study locations and from 0.6 to 1.2 mg/l at the controls. There was no significant difference between study locations and control but seasonal differences were significant with higher values during the wet season ($P<0.05$) (Figure 4.3.9 and 4.3.10). Nitrates occur in water as the end product in the biological breakdown of organic nitrogen. Although not particularly toxic to fish, excess nitrates in the water is often used as an indicator of poor water quality. Nitrate levels over 22 mg/l in natural waters normally indicates man made pollution (Chapman, 1996).

Nitrite ranged from 0.29 to 5.93 mg/l at the project locations and from 0.48 to 3.94 mg/l at the control locations. Seasonal variations were significant but differences between study locations and control were not significant. Nitrites occur in water as an intermediate product in the biological breakdown of organic nitrogen. Nitrite is normally present in only minute quantities in surface waters and rarely higher than 3.5 mg/l (Chapman (1996) indicating that the study area is relatively unpolluted with respect to nitrite.

Ammonium ranged from 0.01 to 1.58 mg/l in the project locations and from 0.31 to 0.56 mg/l at the controls. There was no significant difference between study location and control during the dry season but study location had significantly higher levels than control during the wet season and wet season values were generally significantly higher than dry season concentrations (Figure 4.3i&j) possibly linked to riverine and run-off inputs from coastal settlements and swamps.

Total Ammonia (NH_3 & NH_4^+) is a measure of the most reduced inorganic form of nitrogen in water and includes dissolved ammonia (NH3) and the ammonium ion (NH4+). At higher pH, unionized ammonia (NH_3) will be the predominant form and at a lower pH the ammonia ion (NH_4^+) will be predominant (Bellingham, 1991). The NH_3 is the toxic form to both freshwater and marine fishes. For a pH value of 7.5 and temperature of 25°C, USEPA (1985) recommends a limit of 1.05 mg/l (NH_4^+) for the protection of aquatic life. Apart from a few locations with high values, ammonium levels were generally within the recommended limits indicating unpolluted waters.

Phosphate ranged from 0.11 to 2.9 mg/l at the project locations and from 0.41 to 1.2 mg/l at the controls. Seasonal differences were significant with higher values during the wet season but there was no difference between study location and control (Figure 4.8.9 and 4.8.10). According to Chapman (1996), in most natural surface waters, phosphorus ranges from 0.005 to 0.02 mg/l PO_4-P. Wetzel (2001) reports that concentrations in non-polluted natural waters extend over a wide range from < 0.001 mg/l in ultra-oligotrophic waters to > 0.200 mg/l in highly eutrophic waters. Observed levels of phosphate were therefore considered very high, signifying nutrient enriched waters. Highly values during the wet season is suggestive of riverine and swamp run-off inputs.

Sulphate ranged from 840 to 1860 mg/l at study locations and from 687 to 1500 mg/l at the controls. Levels were significantly higher during the wet than dry season. The mean sulphate levels in water are given as 11 mg/l for freshwater (Livingstone, 1963) and 2700 mg/l for sea water (Hem, 1985) indicating that the observed levels are normal for brackish near coastal water subjected to riverine dilutions of oceanic major constituents.

Generally, all nutrients showed significantly higher values during the wet season which may be attributed to rainfall inputs as well as riverine discharges from settlements and swamps during the rainy season.

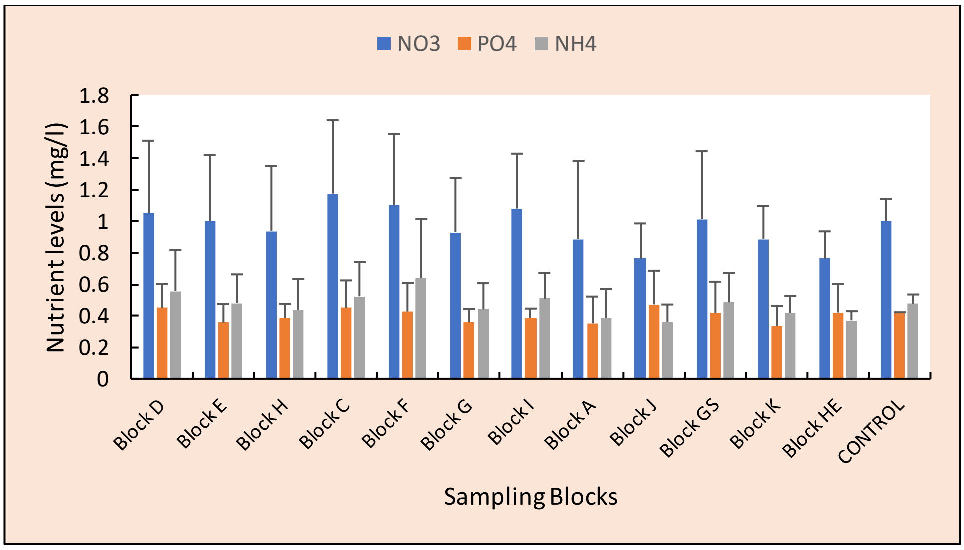

Figure 4.8.9: Nutrient levels in the study area compared with control during the dry season

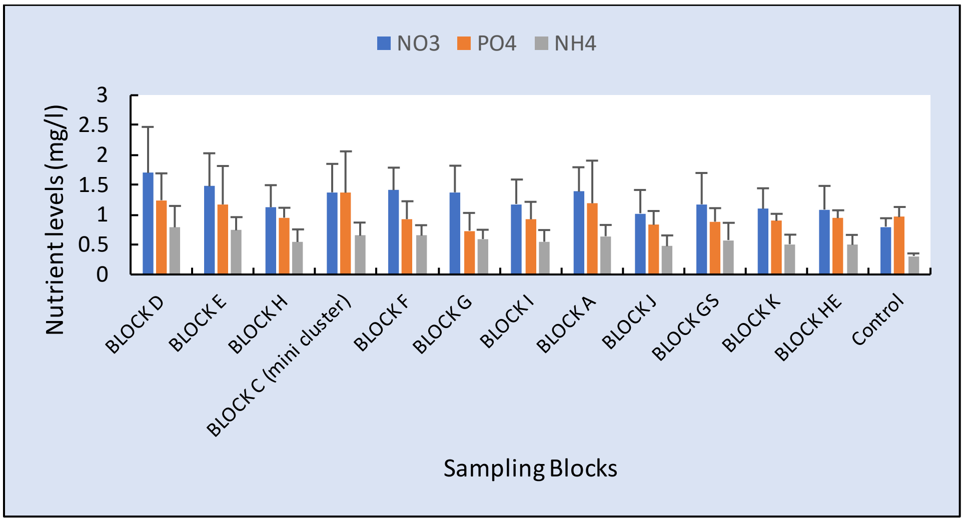

Figure 4.8.10: Nutrient levels in the study area compared with control during the wet season

Major Cations (Na, K, Ca, Mg): Sodium ranged from 1021 to 10448 mg/l at the study area and from 9563 to 9948 mg/l at the controls with no significant difference between study location and control and between wet and dry seasons. Potassium ranged from 301 to 392 mg/l at the project locations and from 353 to 390 mg/l at the controls with no significant difference between study location and control but with significantly higher values during the dry season compared to wet season. Calcium ranged from 309 to 459 mg/l at the project locations and from 400 to 408 mg/l at the controls. There was no significant difference between project location and controls but dry season was significantly higher than wet season values. Magnesium ranged from 1009 to 10062 mg/l at the project locations and from 1124 to 1243 mg/l at the controls. There were no significant differences between project location and controls and between the seasons. Average levels of sodium, potassium, calcium and magnesium in sea water are given as 10,500, 380, 410 and 1350 mg/l respectively (Hem, 1985) indicating that measured values were within normal values for coastal waters.

Heavy metals: The summary results of heavy metals measurement are presented in Table 4.3. Detailed results are given in appendix 4.3. Among the heavy metals measured, barium, cobalt, mercury and vanadium were not detected in the water samples form project area and control locations. Nickel, iron, lead and cadmium showed significant differences with seasons and between project locations and control (Figure 4.8.11 and 4.8.12).

Nickel ranged from 0.012 to 1.1 mg/l at the project locations and 0.125 to 0.974 mg/l at controls. Values were significantly higher during the dry season. Control was higher than project location during the dry season but vice versa during the wet season (Figure 4.3k&l). Nickel values were generally within the background values in the Niger Delta of BDL to 0.52 mg/l and the EU Estuary and Harbour limits of 0.5 mg/l (FAO, 2017) except at the control during the wet season.

Iron ranged from 0.014 to 0.443 mg/l at the project locations and from 0.014 to 0.437 mg/l at the controls with values showing significant differences between study locations and controls and between wet and dry seasons. Values were generally within the limits of natural background in the Niger Delta water BDL-4.74 mg/l) and the EU Estuary and Harbour water limits of 3 mg/l (FAO, 2017).

Lead ranged from 0.002 to 0.853 mg/l at project locations and from 0.094 to 0.289 mg/l at controls with significant differences between study locations and control and between wet and dry seasons. However, all values were generally within the limits of natural background in the Niger Delta water BDL-0.66 mg/l) and the EU Estuary and Harbour water limits of 0.5 mg/l (FAO, 2017).

Cadmium ranged from 0.004 to 0.153 mg/l at the project locations and from 0.005 to 0.018 mg/l at the controls with significant differences between study locations and control and between seasons. The EU estuary and harbour guidelines stipulates a limit of 0.005 mg/l for cadmium. However, cadmium is reported to be acutely toxic to marine species at 0.32 mg/l **(**Alken Muray, 2006) which is far above the measured levels in the study area. Measured levels of copper and chromium were well within the recommended guidelines for Estuary and Harbour waters of 0.5. Zinc was also low, ranging from 0.001 to 0.234 mg/l at the project area and from 0.008 to 0.038 mg/l at the control compared to the Estuary and Harbour waters limit of 50 mg/l. There were no significant differences between seasons and between study locations and control in zinc levels.

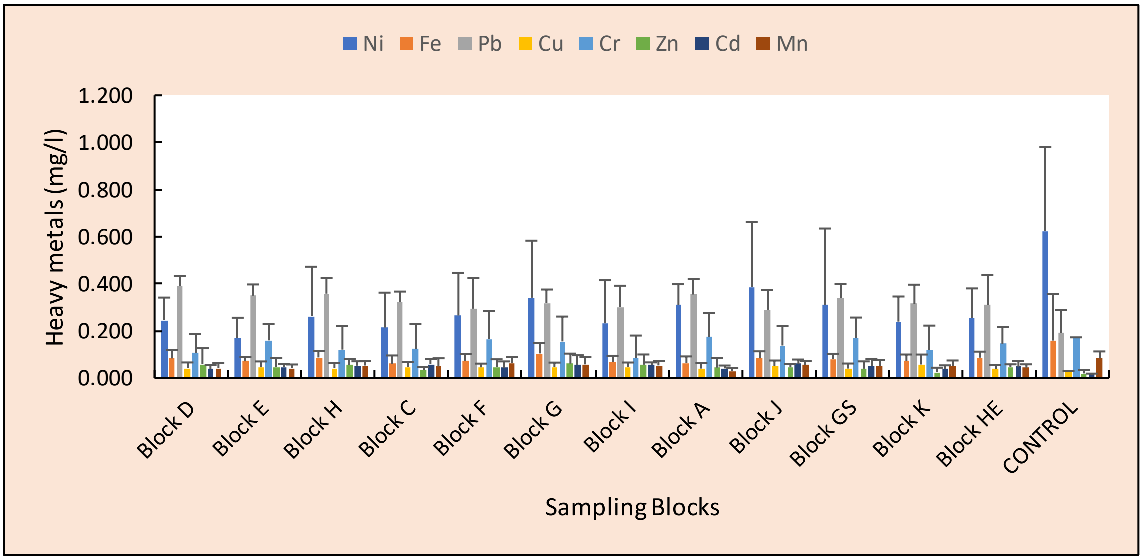

Figure 4.8.11: Heavy metal levels in the study area compared with control during the dry season

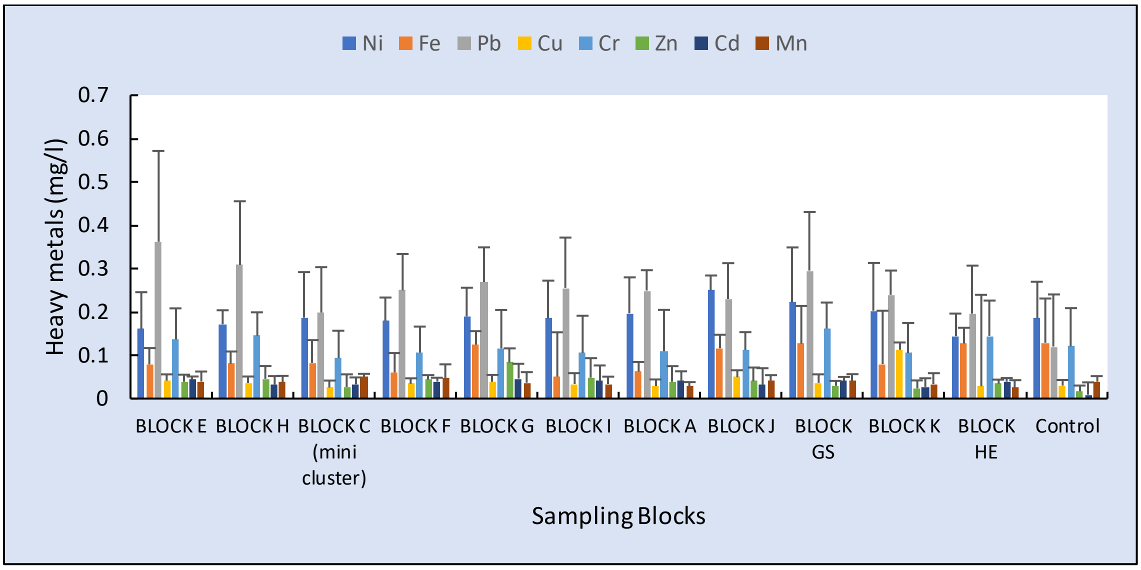

Figure 4.8.12: Heavy metal levels in the study area compared with control during the wet season

Hydrocarbons: All measured hydrocarbons indices including oil and grease, total hydrocarbons, total petroleum hydrocarbons, PAH and the monocyclics-benzene, toluene, ethyl benzene and xylenes (BTEX) were below their respective limits of analytical detection in the project area and control.

Aquatic Microbiology: The hydrocarbons degrading microbials were not observed from the samples from both the project area and control. Both the Total Heterotrophic bacteria and Total Fungi were low in counts amounting only to 10^2 while Sulphur degrading bacteria (SRB) were at levels of 10^3. THB did not show any significant variation between study location and controls and between seasons. TF and SRB showed significant seasonal variations with the dry season being higher than wet for TF and vice versa for SRB. Viable bacteria densities in sea water generally range from 10^3 to 10^6/ml, with counts up to 10^9/g recorded for sediments (Azam *et al.*, 1983). In the water column, the presence of micro-organisms usually decreases with increasing depth. Bacterial abundance is also related to the organic matter concentration and to hydrological phenomena (Azam *et al.*, 1983). Low counts of bacteria reported in this study may be in response to low levels of organic substrate as well as prevailing hydrological conditions.

Coliforms were generally, not detected except during the dry season at project location where it varied from undetected levels to 4 MPN/100ml which is extremely low compared to EU guidelines for estuary and harbour waters of 10000 cfu/100ml. Coliform bacteria are a collection of relatively harmless microorganisms that live in large numbers in the intestines of man and warm- and cold-blooded animals. The criterion for swimming is fewer than 200 colonies/100 ml; for fishing and boating, fewer than 1000 colonies/100 ml (Kentucky Water Watch, 2016). According to Chapman (1996) surface waters, even in remote mountain areas, may contain up to 100 per 100 ml indicating that the observed levels are within natural background levels.

Depth Profile of Measurements

The summary results of depth profiling in measured parameters are shown in Table 4.8.2. Detailed results of depth profile are shown in Appendix 8.0.

Physicochemistry: Significant depth trends were observed in temperature, electrical conductivity, dissolved oxygen and total suspended solids. Hydrogen ion concentration did not show any significant depth trend. Temperature ranged from a mean of 27.4°C at the bottom to 28.6°C at the top during the dry season and from 26.6°C at the bottom to 27.6°C at the top during the wet season showing significant decrease with depth (Figure 4.8.13 and 4.8.14). Such trends are normal in ocean waters and shows the influence of solar insolation on water temperatures.

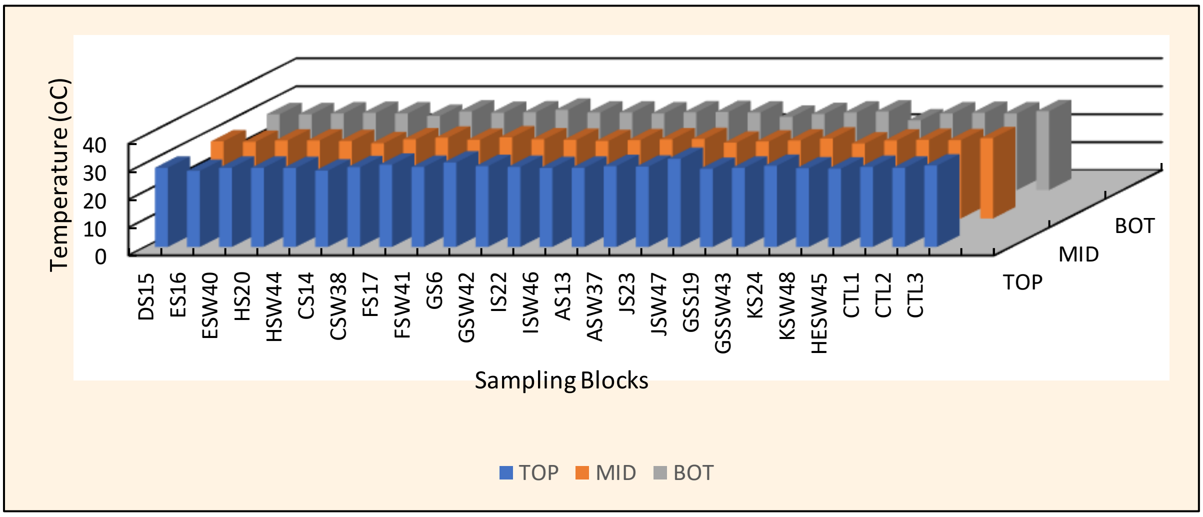

Figure 4.8.13: Depth profile of water temperature in the study area compared with control during the dry season

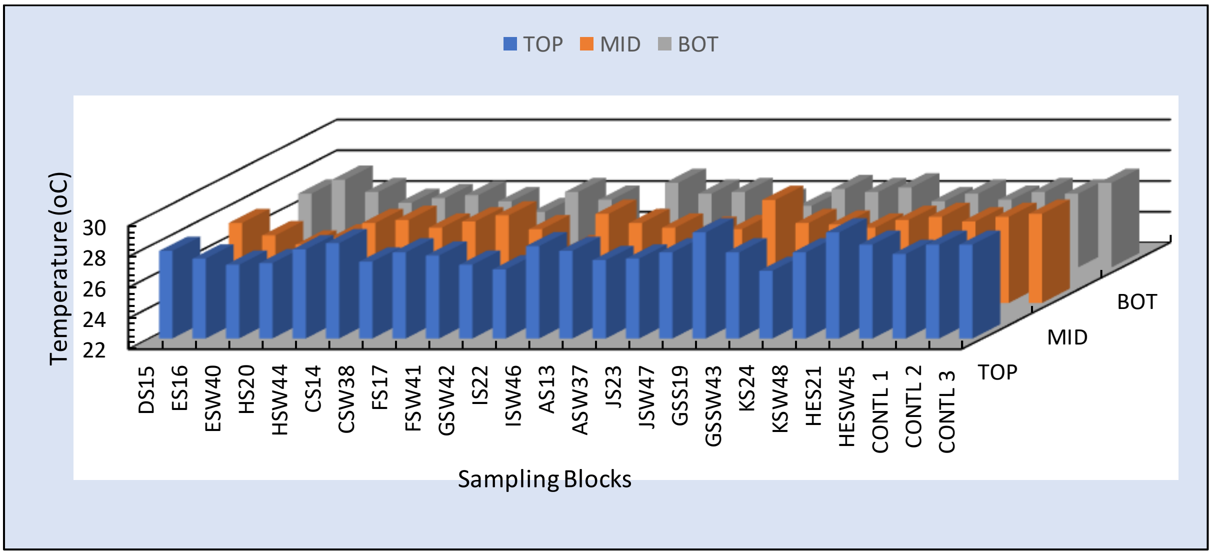

Figure 4.8.14: Depth profile of water temperature in the study area compared with control during the wet season

Table 4.8.2: Summary of water column physicochemical and microbiological measurements in the JK field and control locations

Parameters	Dry season			ANOVA P Values for depth Dry season	Wet season			ANOVA P Values for depth Wet season
	Top	Mid	Bottom		Top	Mid	Bottom	
TEMP (^oC)	28.6±0.8	28±0.5	27.4±0.7	.000	27.6±0.6	27.2±0.6	26.6±0.6	.000
PH	8.54±0.03	8.54±0.03	8.55±0.03	.875	8.39±0.1	8.39±0.12	8.4±0.16	.946
EC (µS/cm)	38459±7759	43384±1942	45572±2449	.000	35830±3607	38435±3009	41665±2734	.000
TURB (NTU)	0±0	0±0	0±0		0.012±0.0587878	0±0	0±0	
DO (mg/l)	5.96±0.08	4.13±0.13	3.56±0.49	.000	5.92±0.08	4.37±0.17	3.83±0.14	.000
TDS (mg/l)	28006.27±755.1	30271.16±1407.87	31872.32±1678.46		25255.6±3935.89	26627.56±2786.03	29109.92±1886.17	
CL (mg/l)	14223.46±759.81	15228.8±1138.48	16139.44±1258.16		14342.68±1417.69	15543.76±1049.91	16691.12±1209.12	
ALK (mg/l)	14.62±2.27	12.88±2.27	13.36±1.35		14.24±2.29	11.04±1.71	8±1.6	
COL (mg/l)	0.01±0	0.01±0.01	0.01±0		0.01±0	0.01±0	0.01±0	
TSS (mg/l)	21.54±3.43	25.28±5.12	25.36±5.14	.006	21.2±1.6	28±3.71	34.88±4.12	.000
COD (mg/l)	180.73±10.64	178.8±11.25	178.96±12.76	.810	178.84±10	178.92±7.82	179.92±9.44	.901
BOD (mg/l)	0.68±0.23	0.46±0.18	0.31±0.15		0.88±0.39	0.92±0.44	1.01±0.34	
NO_3^- (mg/l)	1.03±0.25	0.99±0.33	1.08±0.37	.604	0.85±0.27	1.08±0.26	1.13±0.37	.005
NO_2^- (mg/l)	3.37±0.81	23.95±102.28	19.16±76.52		0.65±0.25	0.78±0.18	0.84±0.21	
SO_4^{2-} (mg/l)	745±76.69	753.52±63.73	766.12±62.89		1508.48±194.68	1600.8±94.06	2266.8±2923.04	
PO_4^{3-} (mg/l)	0.39±0.09	0.41±0.13	0.42±0.1	.690	0.82±0.27	0.97±0.33	1.05±0.3	.034
NH_4^+ (mg/l)	0.48±0.11	0.47±0.15	0.5±0.17	.759	0.41±0.16	0.48±0.12	0.52±0.14	.026
O/G (mg/l)	<0.001	<0.001	<0.001		<0.001	<0.001	<0.001	
THC (mg/l)	<0.001	<0.001	<0.001		<0.001	<0.001	<0.001	
TPH (mg/l)	<0.001	<0.001	<0.001		<0.001	<0.001	<0.001	
PAH (mg/l)	<0.001	<0.001	<0.001		<0.001	<0.001	<0.001	
BTEX (mg/l)	<0.001	<0.001	<0.001		<0.001	<0.001	<0.001	

Parameters	Dry season			ANOVA P Values for depth Dry season	Wet season			ANOVA P Values for depth Wet season
	Top	Mid	Bottom		Top	Mid	Bottom	
Ni (mg/l)	0.267±0.207	0.319±0.143	0.389±0.18	.050	0.159±0.058	0.206±0.053	0.242±0.055	.000
Fe (mg/l)	0.082±0.076	0.085±0.029	0.106±0.03	.170	0.101±0.07	0.108±0.03	0.13±0.033	.094
Pb (mg/l)	0.285±0.099	0.317±0.138	0.359±0.133	.231	0.193±0.097	16.304±73.691	0.259±0.118	.102
Cu (mg/l)	0.04±0.028	0.062±0.041	0.078±0.058	.019	0.062±0.128	0.047±0.023	0.061±0.024	.792
Cr (mg/l)	0.152±0.09	0.164±0.099	0.18±0.105	.637	0.12±0.07	0.15±0.082	0.174±0.092	.032
Zn (mg/l)	0.034±0.032	0.044±0.039	0.059±0.04	.024	0.027±0.019	0.036±0.026	0.052±0.034	.006
Cd (mg/l)	0.036±0.018	0.051±0.02	0.067±0.023	.002	0.029±0.021	0.04±0.021	0.052±0.024	.019
Mn (mg/l)	0.049±0.025	0.057±0.032	0.065±0.032	.002	0.035±0.014	0.047±0.017	0.057±0.018	.000
Ba (mg/l)	<0.01	<0.01	<0.01		<0.01	<0.01	<0.01	
Co (mg/l)	<0.01	<0.01	<0.01		<0.01	<0.01	<0.01	
Hg (mg/l)	<0.01	<0.01	<0.01		<0.01	<0.01	<0.01	
V (mg/l)	<0.01	<0.01	<0.01		<0.01	<0.01	<0.01	
K (mg/l)	371.77±13.74	374.67±14.23	374.89±16.84		358.44±15.84	370.08±13.19	379.8±15.27	
Na (mg/l)	9914.77±304.01	9950.33±326.32	9992.07±263.23		9978.32±173.66	10048.16±135.49	10114.04±110.32	
Mg (mg/l)	1219±48.22	1242.93±27.88	1235.59±63.17		1220.08±27.19	1233.68±29.68	1251.04±27.01	
Ca (mg/l)	409.23±6.99	412.59±7.92	416.59±12.13		413.6±7.64	423.36±8.87	434.36±14.9	
HUF (cfu/ml)	<0.01	<0.01	<0.01		0.02±0.01	0.02±0	0.03±0.02	
HUB (cfu/ml)	<0.01	<0.01	<0.01		0.05±0.04	0.04±0.02	0.04±0.01	
THB (cfu/ml) x 10^2	2.17±0.15	1.94±0.18	1.91±0.22	.295	2±0.36	1.9±0.35	1.68±0.39	.011
THF (cfu/ml) x 10^2	1.25±0.28	2.55±2.78	2.15±2.55	.093	0.74±0.55	0.71±0.56	0.52±0.55	.358
SRB	5.38±4.22	1.26±0.07	1.01±0.17		1.37±0.16	1.47±0.19	1.43±0.23	.263
Coliforms (MPN/100 ml)	0±0	0.08±0.28	0.21±0.58		0±0	0±0	0±0	

Source: JK EIA Field studies

Electrical conductivity ranged from a mean of 38459 at the top to 45572 µS/cm at the bottom during the dry season and from 35830 at the top to 41665 µS/cm at the bottom during the wet season showing significant increase with depth (Figure 4.8.15 and 4.8.16). The represents the natural trend of salt concentration in the sea since the density of water which is directly related to salinity increases with depth. Total suspended solids followed a similar trend as conductivity, increasing from a mean of 21.54 at the top to 25.36 mg/l at the bottom during the dry season and from 21.2 at the top to 34.88 mg/l at the bottom during the wet season. This is attributed to sinking of inorganic and organic particulates from surface and well as resuspension of sediments from the bottom in response to tidal and other hydrodynamic conditions.

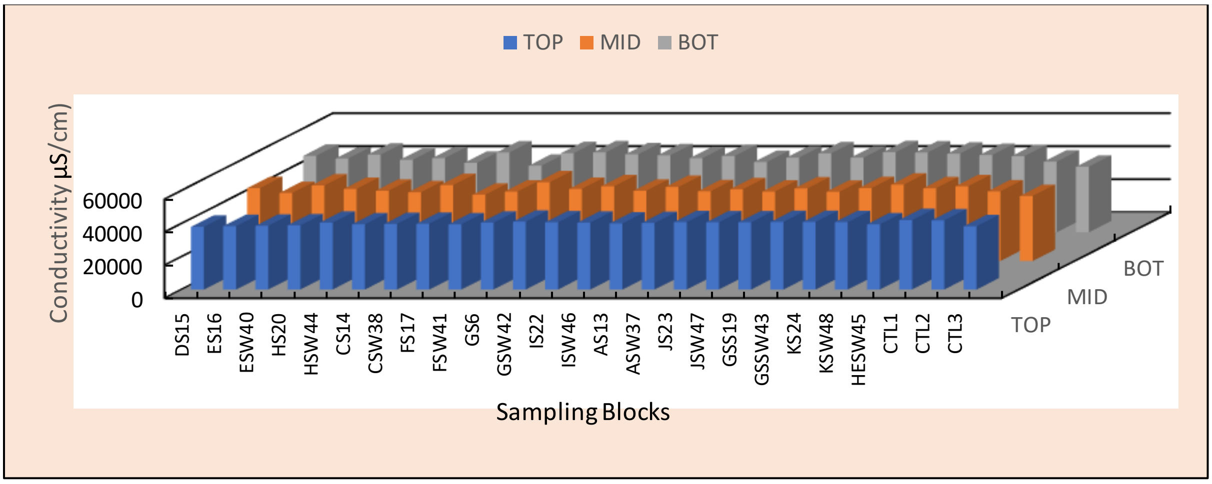

Figure 4.8.15: Depth profile of electrical conductivity in the study area compared with control during the dry season

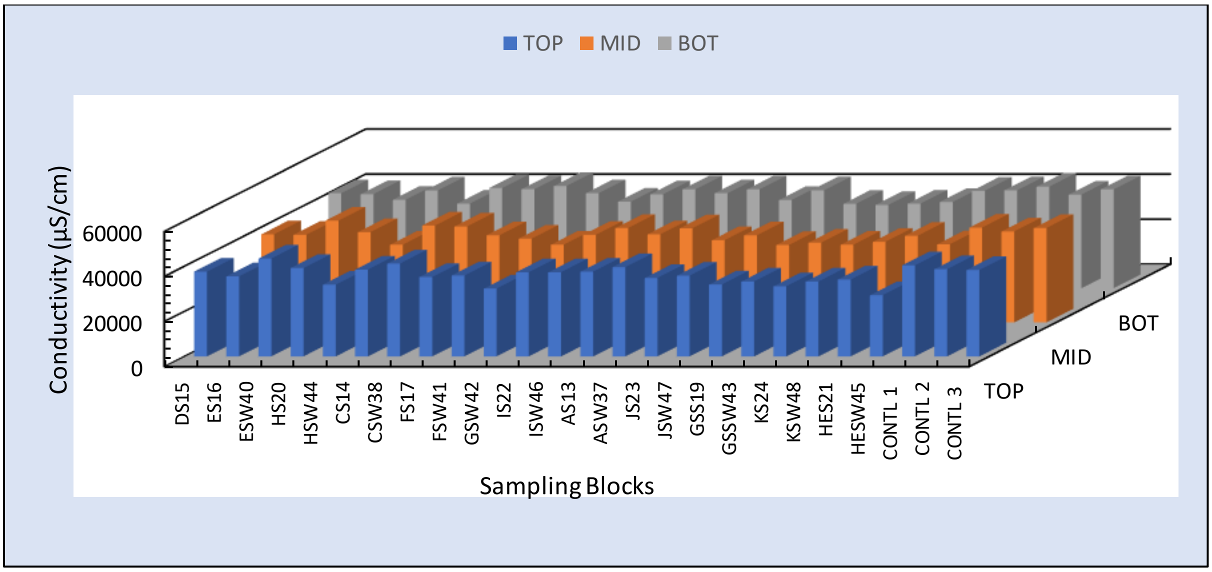

Figure 4.8.16: Depth profile of electrical conductivity in the study area compared with control during the wet season

Dissolved oxygen ranged from a mean of 5.95 mg/l at the surface to 3.56 mg/l at the bottom during the dry season and from 5,92 mg/l at the top to 3.83 mg/l at the bottom during the wet season showing significant decrease with depth (Figure 4.8.17 and 4.8.18). The observed depth profile shows the expected natural trend and is attributable to mechanisms of DO inputs and output in the marine environment. Disssolved enters the ocean by diffusion from air at the surface as well as from photosynthetic phytoplankton dominant at the surface of the ocean. In contrast, DO is consumed at depths through respiration, organic matter degradation and other redox processes leading to low bottom levels.

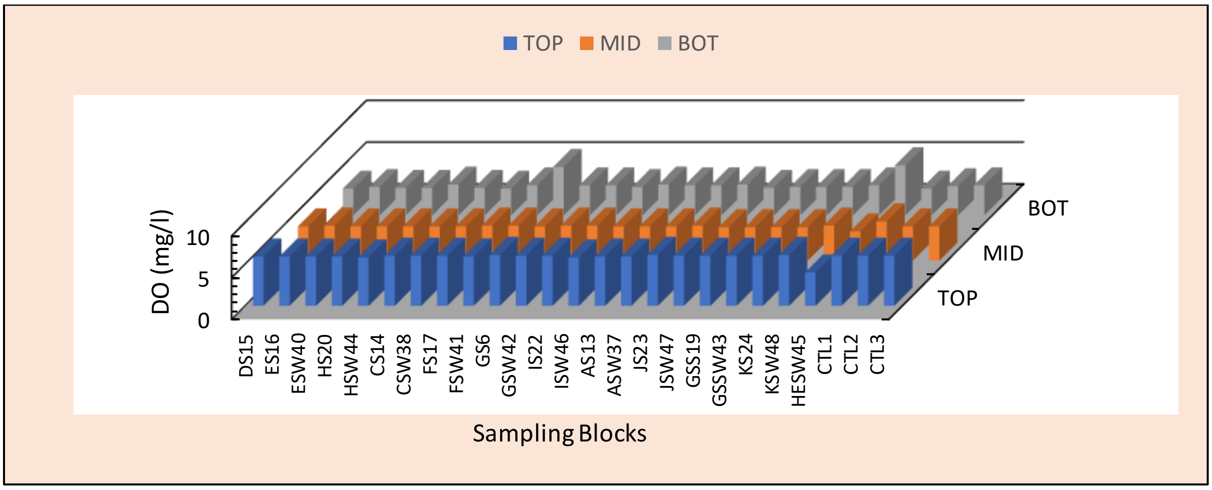

Figure 4.8.17: Depth profile of DO in the study area compared with control during the dry season

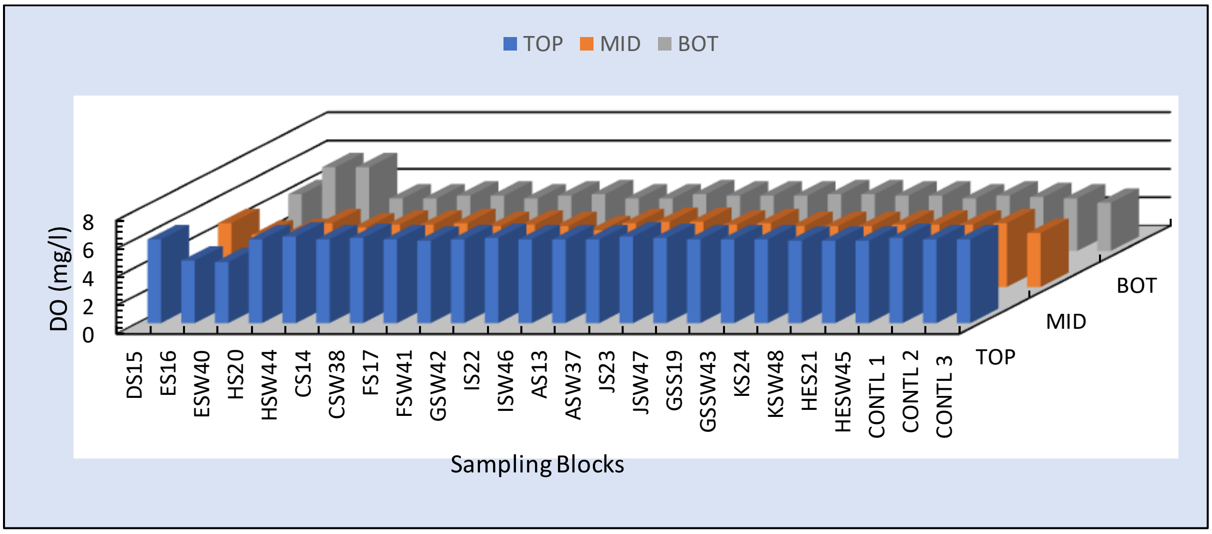

Figure 4.8.18: Depth profile of DO in the study area compared with control during the wet season

The nutrients including phosphate and ammonium did not show any significant depth trends during both wet and dry seasons but nitrate was significantly higher at the bottom during the wet season (Figure 4.8.19). Nutrients follow a natural trend of assimilation at the surface and regeneration at the bottom associated with microbial mineralization of organic matter.

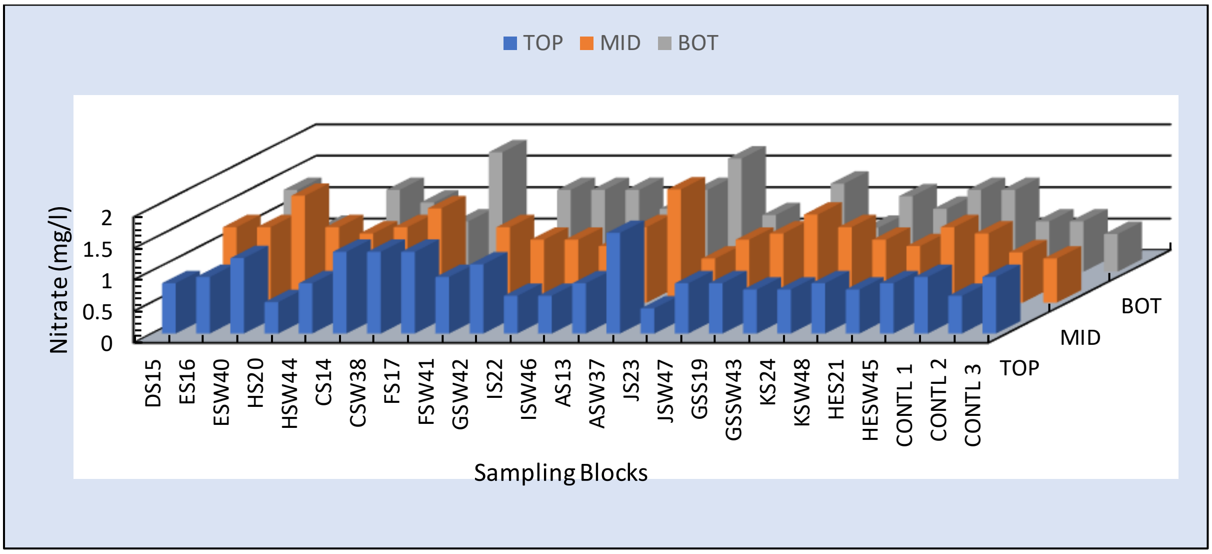

Figure 4.8.19: Depth profile of nitrate in the study area compared with control during the wet season

Hydrocarbons: Measured hydrocarbons including oil and grease, total hydrocarbons, total petroeum hydrocarbon.PAH and BTEX were not detected in the water column from surface to bottom.

Heavy metals: A number of heavy metals including nickel, copper, chromium, zinc, cadmium and manganese, showed significant depth trends mainly represented by increase with depth. For instance, nickel increased significantly from a mean of 0.267 mg/l at the top to 0.389 mg/l at the bottom during the dry season and from 0.159 mg/l at the top to 0.242 mg/l at the bottom during the wet season (Figure 4.8.20 and 4.8.21). Although other metals such as iron and lead did not show a significant trend they were relatively still higher at the bottom than surface (Figure 4.8.22 to 4.8.25). All metal levels were still within recommended guidelines and for Estuary and Harbour water and as such even the bottom were not polluted.

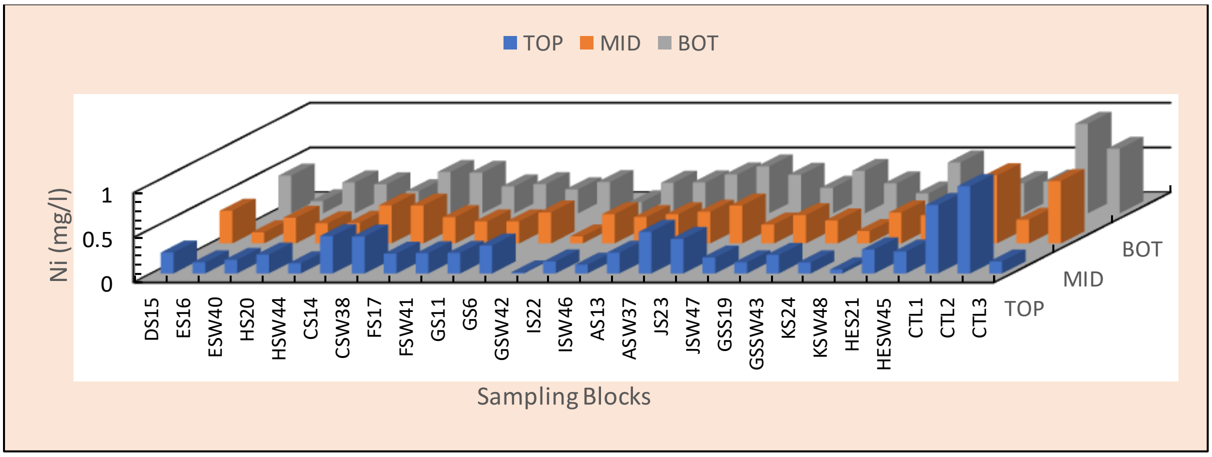

Figure 4.8.20: Depth profile of nickel in the study area compared with control during the dry season

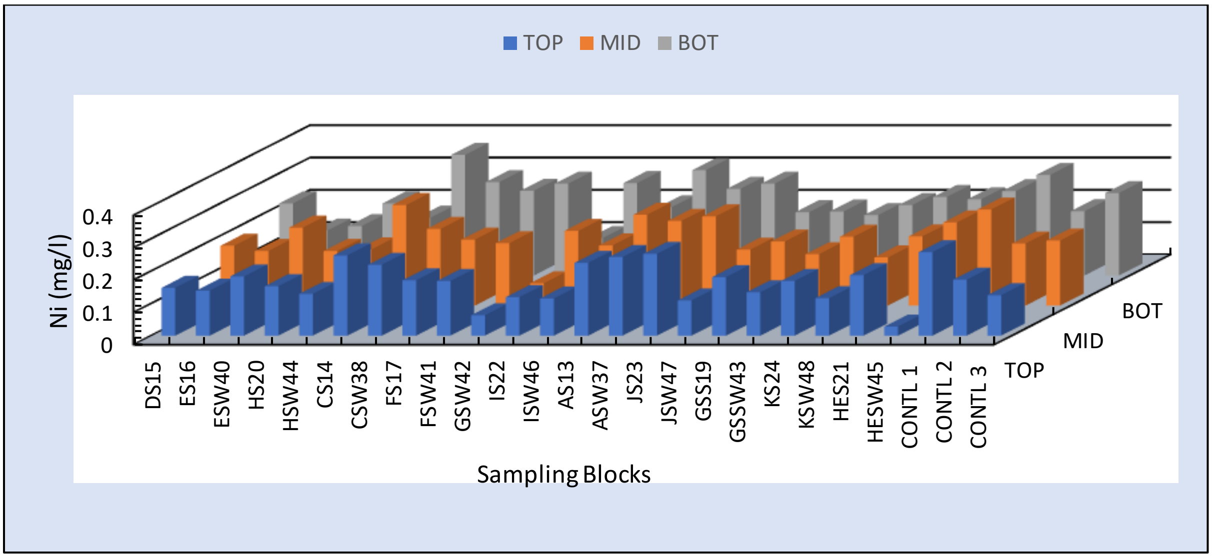

Figure 4.8.21: Depth profile of nickel in the study area compared with control during the wet season

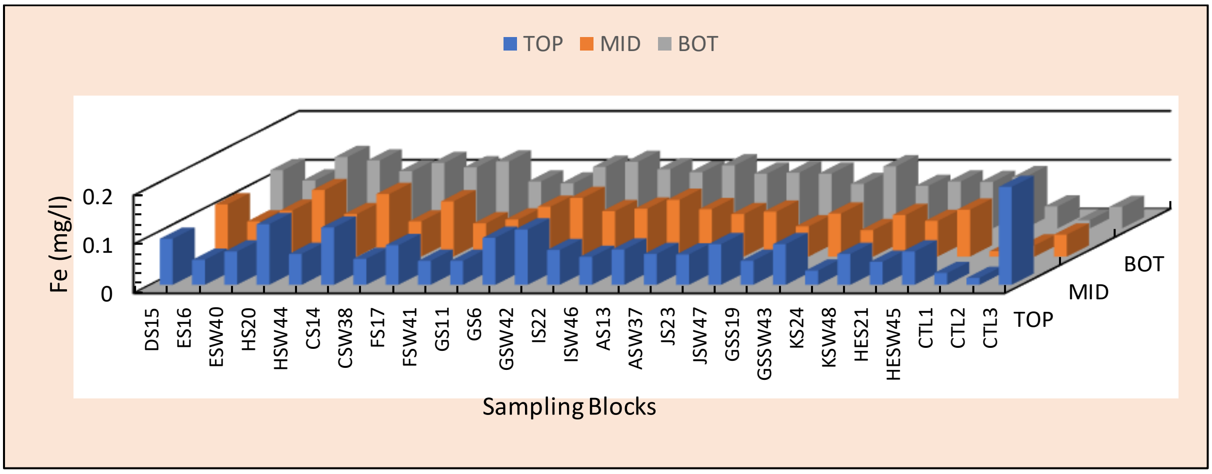

Figure 4.8.22: Depth profile of iron in the study area compared with control during the dry season

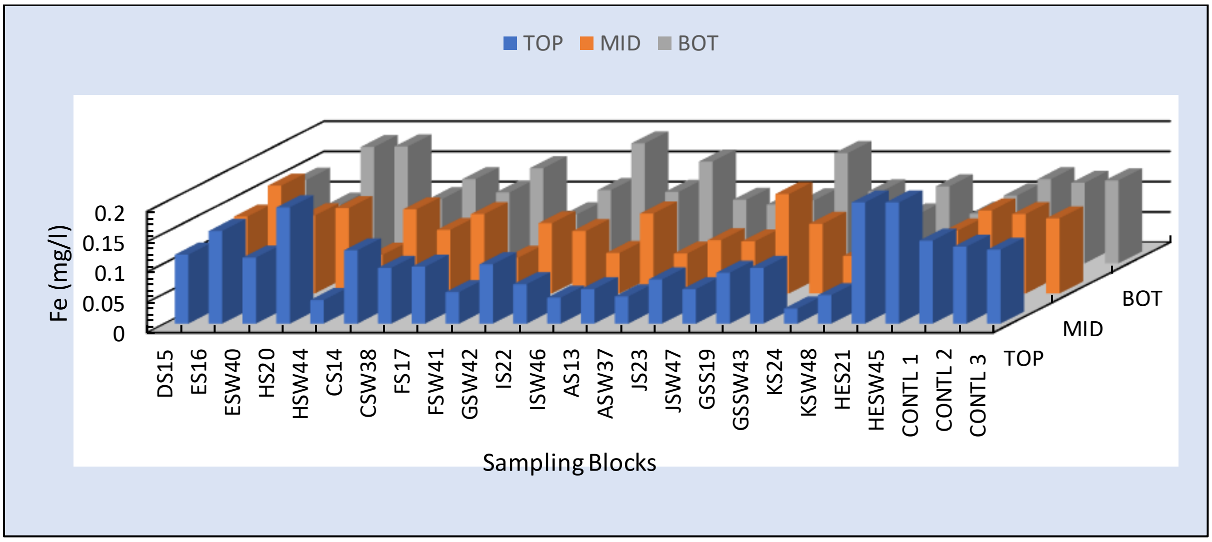

Figure 4.8.23: Depth profile of iron in the study area compared with control during the wet season

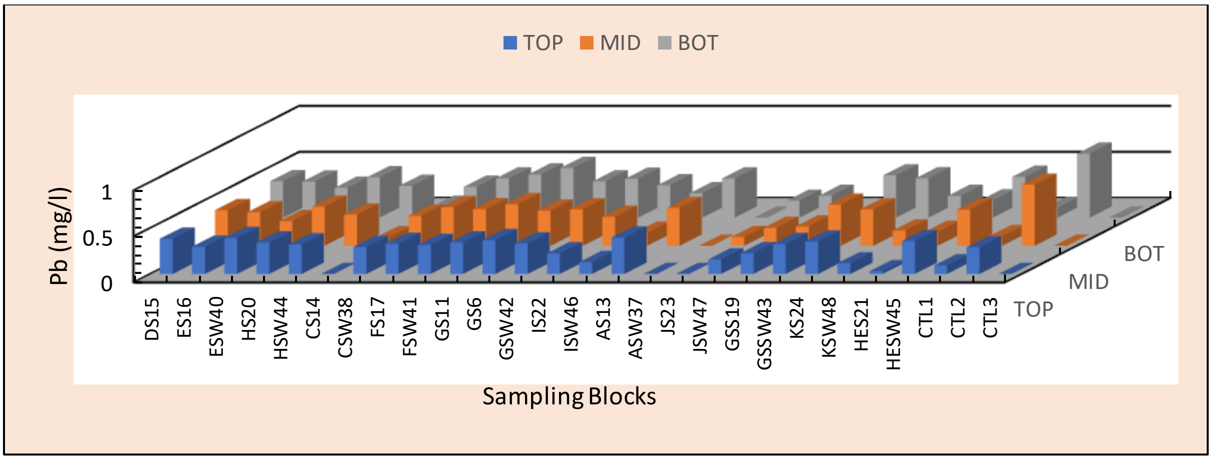

Figure 4.8.24: Depth profile of lead in the study area compared with control during the dry season

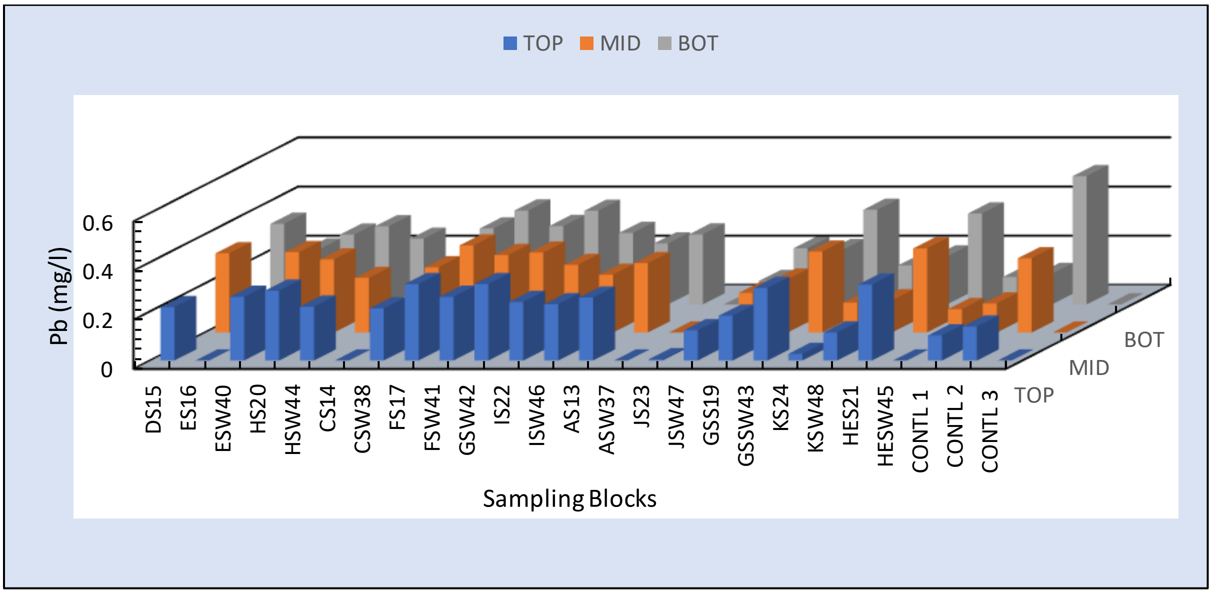

Figure 4.8.25: Depth profile of lead in the study area compared with control during the wet season

Aquatic Microbiology: The measured microbial indices including HUB, HUF, THB, TF and SRB did not show any depth trend except THB during the wet season which decreased significantly from 2 x 10^2 cfu/100ml at the top to 1.68 x 10^2 cfu/100ml at the bottom. The reduction cannot be attributed to paucity of organic substrate since COD and BOD actually showed relative increases towards the bottom during the wet season (Table 4.8.2).

4.9: Sediment quality

The summary results of sediment quality measurements in the JK field is presented in Table 4.9.1. Detailed results are presented in Appendix 8.0.

Sediment Physicochemistry

Sediment Texture: The sediments were generally muddy with 0% sand at all locations. Silt ranged from 43.1 to 57.4% at the study locations and from 15.8 to 73.8% at the controls. Clay ranged from 42.7 to 56.8% at study locations and from 26.2 to 84.2% at controls. Silt and clay did not show significant seasonal variations but controls were significantly higher than project locations in clay and vice versa in silt (Figure 4.9.1 and 4.9.2).

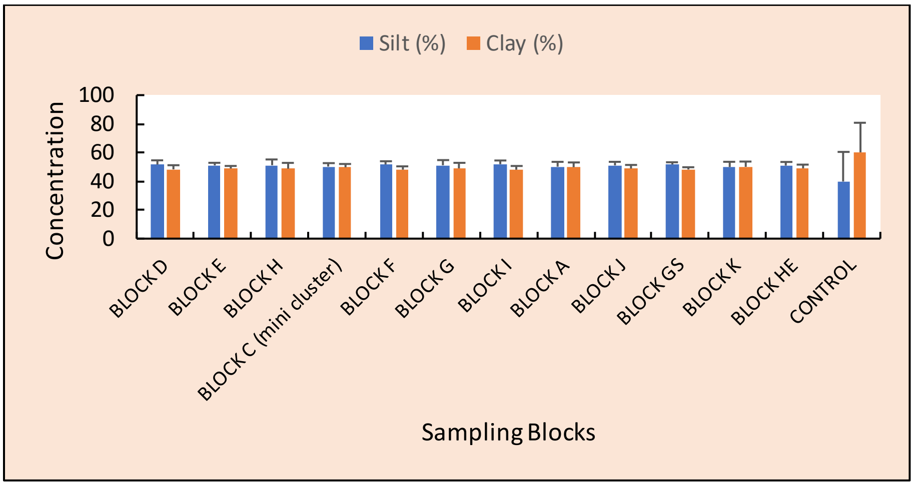

Figure 4.9.1: Particle size distribution in the study area compared with control during the dry season

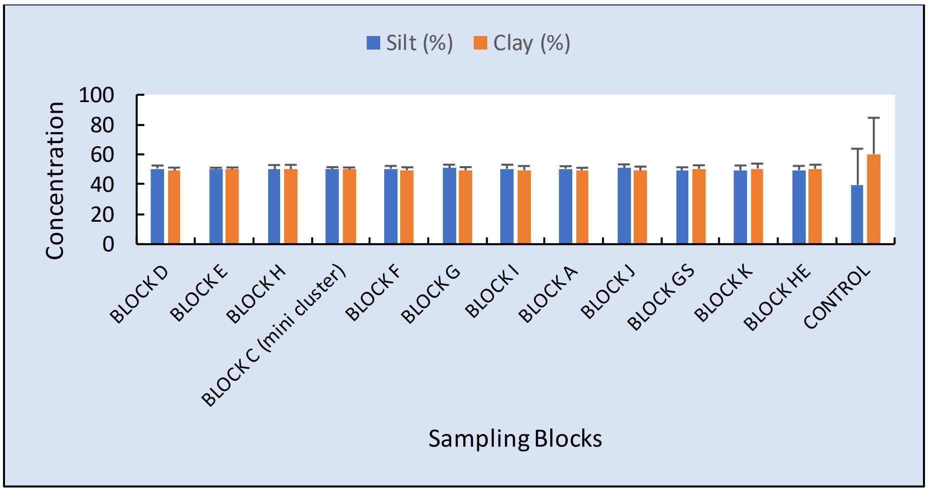

Figure 4.9.2: Particle size distribution in the study area compared with control during the wet season

Temperature, pH, Redox Potential, TOC: Temperature ranged from 15.1 to 18.7°C at the project locations and from 16.8 to 21.5°C at controls with significantly higher values at controls but no significant seasonal variations. Sediment temperatures are considered normal in relation to overlying water column temperatures.

Hydrogen ion concentration (pH) ranged from 6.98 to 8.19 at the study locations and from 7.32 to 8.03 at the controls with no significant difference between study location and control (Figure 4.4.3 and 4.4.4). Hydrogen ion concentration were significantly higher during the wet than dry season. Zobel (1946) reports that recent sediments display a pH range from 6.4 to 9.5. Siever *et al*. (1965) gave the range of pH values in recent ocean sediment as being between 7.00 and 7.85 with most values between 7.2 and 7.7. Observed values are therefore normal for ocean waters

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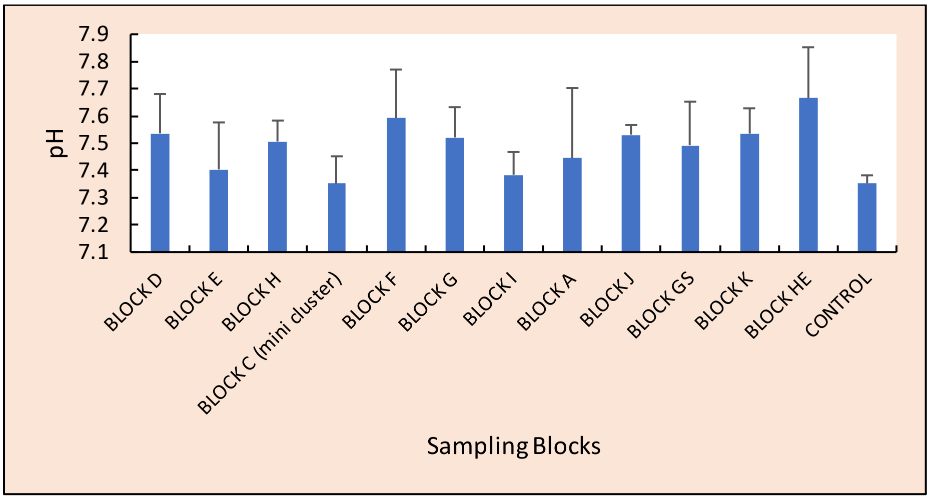


Figure 4.9.3: Levels of pH in sediments of the study area compared with control during the dry season

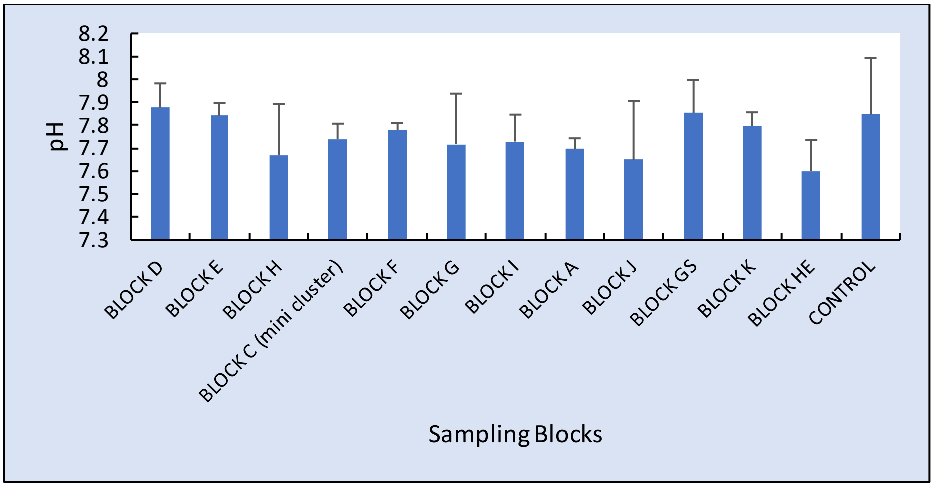


Figure 4.9.4: Levels of pH in sediments of the study area compared with control during the wet season

Table 4.9.1: Summary of sediment physicochemical and microbiological measurements in the JK field and control locations

Parameters	Dry season				ANOVA P Dry vs Control	Wet season				ANOVA P Wet vs Control	ANOVA P Dry vs Wet	Normal values
	Project		Control			Project		Control				
	Range	Mean	Range	Mean		Range	Mean	Range	Mean			
pH	6.98-7.89	7.49±0.17	7.32-7.4	7.4±0.03	.165	6.98-8.19	7.75±0.165	7.42-8.03	7.74±0.28	.315	.000	6.4-9.9[i]
Redox (mV)	-69.8-19.7	-35.9±13.2	-28.8--18.5	-24.1±4	.149	-68.9-39.7	-46±12	-63.8--23.6	-46.3±17	.291	.000	+700-(-300)[ii]
Temp. (°C)	15.1-18.7	16.8±0.7	17.6-21.5	20±1.47	.000	15.1-18.4	16.75±0.57	16.8-20.8	19±1.5	.000	.540	
Cl^- (mg/kg)	9280-10833	9113±1047	8956-9786	9325.75±301.3	.741	4661-10914	9196±627	9048-9763	9386.5±255	.621	.504	
TOC (%)	0.19-3.81	1.5±0.75	0.77-1.69	1.22±0.39	.781	0.21-3.13	1.58±0.72	0.87-1.83	1.22±0.36	.203	.487	<3.0[v]
NO_3^- (mg/kg)	0.1-1.5	0.68±0.33	0.5-0.9	0.7±0.14	.911	0.1-7.7	1.91±1.46	2-2.8	2.4±0.4	.243	.000	
PO_4^{3-} (mg/kg)	0.1-0.89	0.36±0.21	0.14-0.29	0.19±0.06	.229	0.04-0.73	0.37±0.16	0.1-0.8	0.4±0.25	.173	.765	
NH_4^+ (mg/kg)	0.05-0.65	0.33±0.15	0.23-0.42	0.33±0.07	.980	0.01-3.58	0.878±0.69	0.93-1.3	1.12±0.19	.258	.000	
Sand (%)	0-0	0±0	0-0	0±0		0-0	0±0	0-0	0±0			
Silt (%)	43.1-57.4	51±3	15.8-70.3	39.8±20.6	.000	43.4-54.5	50±2.4	19.5-73.8	40.7±21.1	.000	.035	
Clay (%)	42.7-56.8	49±3	29.6-84.2	60.1±20.6	.000	45.4-56.6	49.8±2	26.2-80.5	59.3±21.1	.000	.027	
THC (mg/kg)	5.7-20	9.5±3.6	6.3-17	10.5±4.38	.662	5.8-22.5	11.74±4.17	6.7-15	8.975±3.48	.398	.000	
TPH (mg/kg)	0.03-0.08	0.05±0.02	0.02-0.02	0.02±0		0.04-0.11	0.06±0.03	0-0	0±0			
PAH (mg/kg)	0-0	0±0	0-0	0±0		0-0	0±0	0-0	0±0			
BTEX (mg/kg)	0-0	0±0	0-0	0±0		0-0	0±0	0-0	0±0			
Ni (mg/kg)	2.877-322.108	59.38±43.55	20.055-43.561	29.55±8.77	.178	1.028-125.356	43.66±26.53	19.128-33.215	23.98±5.57	.220	.001	BDL-28.6[iii] 21(52)[iv]

Parameters	Dry season				ANOVA P Dry vs Control	Wet season				ANOVA P Wet vs Control	ANOVA P Dry vs Wet	Normal values
	Project		Control			Project		Control				
	Range	Mean	Range	Mean		Range	Mean	Range	Mean			
Fe (mg/kg)	4194-7893	6724.4±657.9	5789-7342	6756.5±601.7	.348	6539-12043	7843±896	7489-8456	7825.5±390	.862	.000	42.0-22700[iii]
Pb (mg/kg)	0.955-5.803	3.6±0.98	4.824-25.406	18.78±8.24	.000	0.124-3.224	1.46±0.7	3.021-21.741	15.85±7.52	.000	.000	BDL-37[iii] 47(220)[iv]
Cu (mg/kg)	2.602-16.133	8.59±2.89	0.403-10.235	3.46±3.95	.000	2.118-12.151	5.89±2.21	0.352-4.403	1.7±1.6	.000	.000	34 (270)[iv]
Cr (mg/kg)	0.209-103.513	30.92±19.86	26.235-26.235	26.24±0	.010	0.164-59.167	20.5±11.67	8.927-8.927	8.93±0	.004	.000	BDL-8.0[iii] 81(370)[iv]
Zn (mg/kg)	5.1-61.098	29.09±10.99	8.974-30.125	19.69±8.18	.047	0.322-98.784	20.36±15.96	3.911-13.655	9.16±3.57	.239	.343	1-76[iii] 150(410)[iv]
Cd (mg/kg)	0.238-13.258	6.15±2.79	2.191-3.245	2.718±0.53	.005	0.238-13.258	4.89±2.69	2.191-3.245	2.72±0.53	.015	.011	BDL-8.0[iii] 1.2(9.6)[iv]
Ba (mg/kg)	5-16	10.76±2.62	11-17	13.25±2.28	.061	5-140	11±14	8-16	11±3.32	.896	.891	
Co (mg/kg)	10.124-18.954	14.13±2.16	16.123-20.123	18.18±1.66	.001	4.231-19.124	9.12±2.51	10.235-13.284	11.67±1.23	.056	.000	
Ag (mg/kg)	0-0	0±0	0-0	0±0		0-0	0±0	0-0	0±0			1(3.7)[iv]
V (mg/kg)	0-0	0±0	0-0	0±0		0-0	0±0	0-0	0±0			BDL-40.8[iii]
K (mg/kg)	513-757	599.37±62.67	586-680.2	633.38±33.68	.174	513-693	559.7±33.6	544-631	595.75±33.35	.008	.000	
Na (mg/kg)	1215-12560	11354±1091.63	10345-11325	10726.25±400	.195	11012-13952	11976±783	12856-13922	13458.5±408.75	.000	.000	
Mg (mg/kg)	1986-2982	2433.65±276.31	2345-2751.2	2605±154	.111	2115-2993	2386±182	2273-2617	2472.5±124.98	.150	.162	

Parameters	Dry season				ANOVA P Dry vs Control	Wet season				ANOVA P Wet vs Control	ANOVA P Dry vs Wet	Normal values
	Project		Control			Project		Control				
	Range	Mean	Range	Mean		Range	Mean	Range	Mean			
Ca (mg/kg)	1009-1526	1204.87±95.16	609-1325	792.25±307.6	.000	1005-1471	1211±102	1264-1398	1339.25±51.36	.011	.692	
HUF x 10^2	0-0	0±0	0-0	0±0		0.002-0.33	0.036±0.05	0.03-0.04	0.037±0.01			
HUBx 10^1	0.2-0.4	0.26±0.08	0-0	0±0		0.01-2.4	0.42±0.47	0.18-0.22	0.21±0.02	.554		
THB x 10^2	0.21-9.2	2.17±0.78	2.14-2.28	2.19±0.053	.939	0.06-219	3.33±22.26	0.07-2.16	0.83±0.86	.821	.612	
THF x 10^2	0.1-9.7	0.791±0.96	0.61-0.92	0.74±0.13	.985	0.06-3	1.69±0.96	0.09-1.45	1±0.54	.217	.000	
SRB x 10^5	0-0	0±0	0-0	0±0		3.2-88	10.7±16	5.1-44	15.65±16.42	.373		
[i](Zobel, 1946), [ii](DeLaune *et al*., 1976), [iii](RPI,1985), [iv](NOAA-ERL& (ERM)), [v](USEPA, 2002), [vi](Canadian-ISQG & PEL)												

Redox potentials ranged from -69.8 to 39.7 mV at project locations and from -28.8 to -18.5 mV at the controls (Figure 4.8.5 and 4.8.6). There were no significant difference between study locations and control but wet season was significantly more reducing than dry season. Submerged sediments display a range of redox potentials from highly oxidizing (+700 mV) to highly reducing (-300 mV) (DeLaune *et al*., 1976). According to Colman and Holand (2000) redox transition between 0 mV and -150 mV is attributable to reduction of SO_4^{2-} to S^{2-} which corresponds to observed values in the present study.

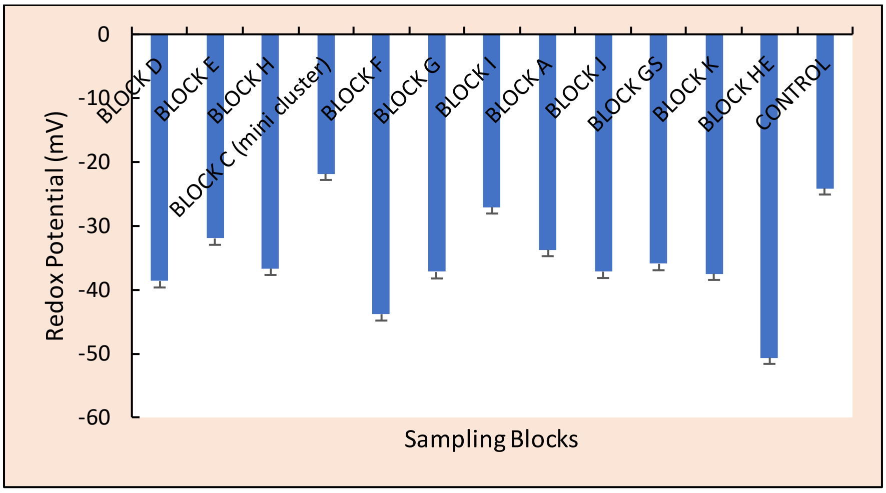


Figure 4.8.5: Redox potential levels in sediments of the study area compared with control during the dry season

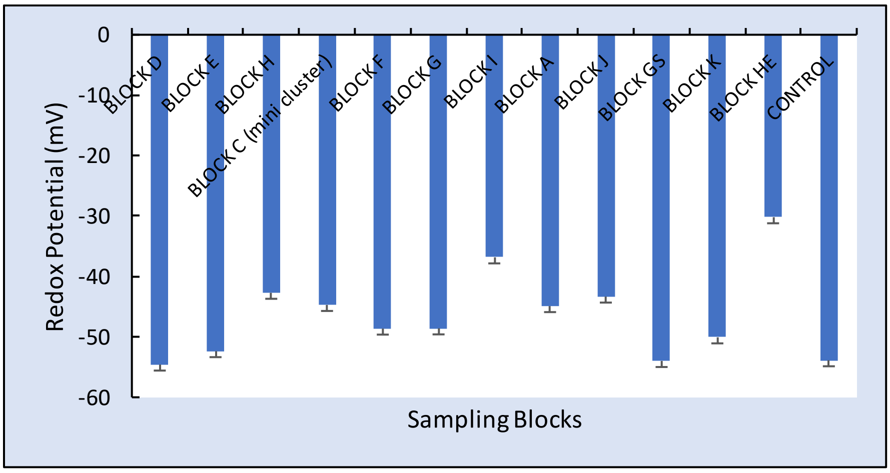


Figure 4.8.6: Redox potential levels in sediments of the study area compared with control during the wet season

Total Organic Carbon (TOC) ranged from 0.19 to 3.81% at the study location and from 0.77 to 1.83% at the controls (Figure 4.8.7 and 4.8.8). TOC did not show any significant difference between study locations and control and between seasons. USEPA (2002) recommends that values of TOC above 3% be interpreted as high while values less than 1% are low. During the 2010 BP Macondo-1 well oil spill in the Gulf of Mexico, very high levels (10-28 %) of organic carbon were recorded within the heavily oiled sediments in contrast to those in pristine sediments (<3 %) (Natter *et al*., 2012). TOC levels in the field were generally low and below levels of concern.

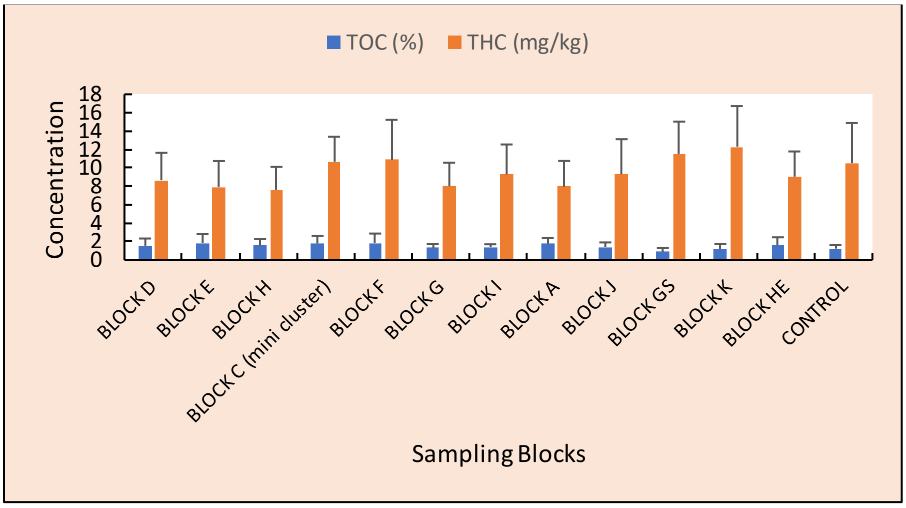


Figure 4.8.7: TOC levels in sediments of the study area compared with control during the dry season

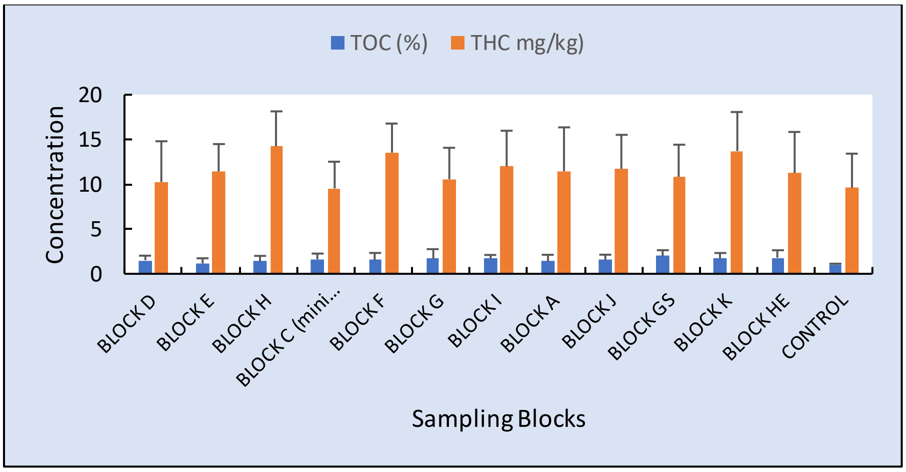


Figure 4.8.8: TOC levels in sediments of the study area compared with control during the wet season

Cations and Anions: The major ions including sodium, potassium, magnesium, calcium and chloride were closely related to overlying water column levels. Chloride ranged from 4661 to 10914 mg/kg with no significant difference between study locations and control and between seasons. Sodium ranged from 1215 to 13952 mg/kg with no significant difference between study location and control during the dry season but during the wet season control was significantly higher than project locations and wet season was significantly higher than dry season. Potassium ranged from 513 to 757 mg/kg with significantly higher control than study location during the wet season but generally significantly higher dry season values. Magnesium ranged from 1986 to 2993 mg/kg with no significant difference between study area and control and between seasons. Similarly, calcium ranged from 609 to 1526 mg/kg with no significant spatial and seasonal differences. Major cations are important with respect to the base exchange capacity (BEC) of sediments. Base exchange capacity of sediment reflects the content of exchangeable cations in sediments. The larger the base exchange value of sediment, the larger the capacity of cation exchange with hydronium (H^+) ions (i.e. Acid Exchange Capacity (ANC)) and the larger the ability to buffer acidic deposition (Bohan and Hongxiao, 1994). From studies in some water systems of Southwestern China, Bohan and Hongxiao (1994) reported that the amount of exchangeable Ca^{2+}, Mg^{2+} and Na^+ in sediments was positively correlated to concentrations in water and concluded that the quality of a natural water system would be closely correlated with the composition of the mineral phase through the chemical weathering process. Although the alkalinity of the overlying waters was low, the high levels of exchangeable cations would provide adequate protection from moderate acidic conditions.

Heavy Metals: Although the term heavy metals is usually used to suggest pollution or toxic effects, a number of heavy metals are of known nutritional importance (e.g. cobalt, chromium III, copper, iron, manganese, molybdenum, selenium and zinc). Boron, nickel, beryllium and vanadium have possible health requirements while Aluminum, Antimony, Arsenic, Barium, Beryllium, Cadmium, Lead, Mercury, Silver, Strontium and thallium are said to have no known nutritional benefits (Goyer *et al*., 2004). Silver and Vanadium were not detected in the sediments during the present studies.

Iron ranged from 4197 to 12043 mg/kg at the project locations and from 5789 to 8456 mg/kg at the controls with wet season showing significantly higher values than dry seas but with no difference between project and control locations (Figure 4.8.9 and 4.8.10). Although higher than all other metals, the concentrations of iron are considered normal for the sediments. Iron and manganese are usually considered of major metals along with sodium, potassium, calcium, magnesium because their concentrations are usually high compared with those of other cations in natural waters. Concentrations can vary widely in relation to the sedimentary geology of the area (RPI, 1984). RPI (1985) reported a range of 42-22700 for the Niger Delta sediments. Iron in UK marine sediments is reported to be as high as 20,800 mg/kg (UK Marine SACs, 2001).

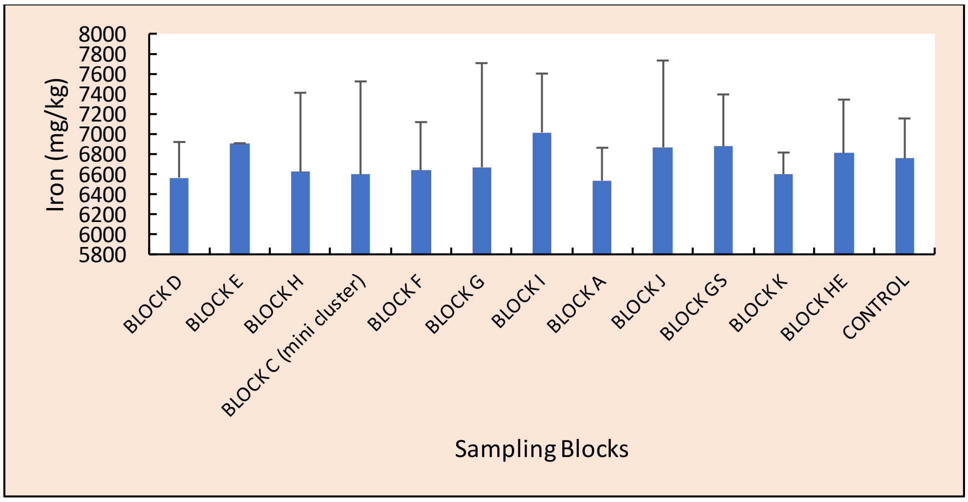


Figure 4.8.9: Iron levels in sediments of the study area compared with control during the dry season

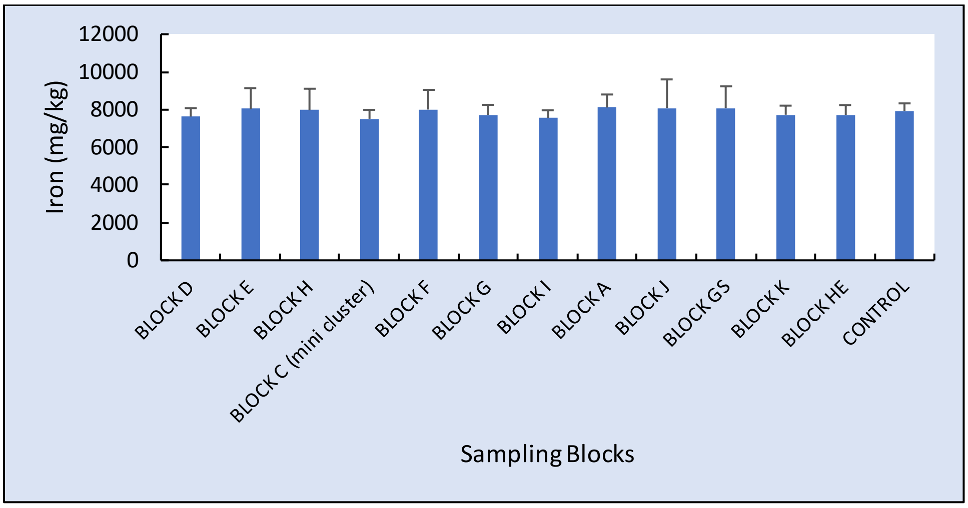


Figure 4.8.10: Iron levels in sediments of the study area compared with control during the wet season

Nickel ranged from 1.028 to 322.1 mg/kg at the project locations and from 19.128 to 43.651 mg/kg at control locations (Figure 4.8.11 and 4.8.12). Nickel did not show any significant difference in concentration between study locations and control but levels were significantly higher during dry compared to wet season. Background levels in the Niger Delta area is reported as BDL- 28.6 mg/kg (RPI, 1985). The United States National Ocean and Atmospheric Administration (NOAA) recommended Effect Range Median (ERM) levels is 52 mg/kg. The Nigerian DPR target value is 35 while the intervention value is 210 mg/kg. Several locations were in exceedance of the various set limits showing occurrence of nickel pollution in the project area. Locations with high nickel values included Block J SW35 and Block G ASW1, ASW7, SW7 and SW8. Small amounts of Nickel are needed by the human body to produce red blood cells, however, in excessive amounts, can become mildly toxic. Nickel can accumulate in aquatic life, but its presence is not magnified along food chains (Lenntech, 2015).

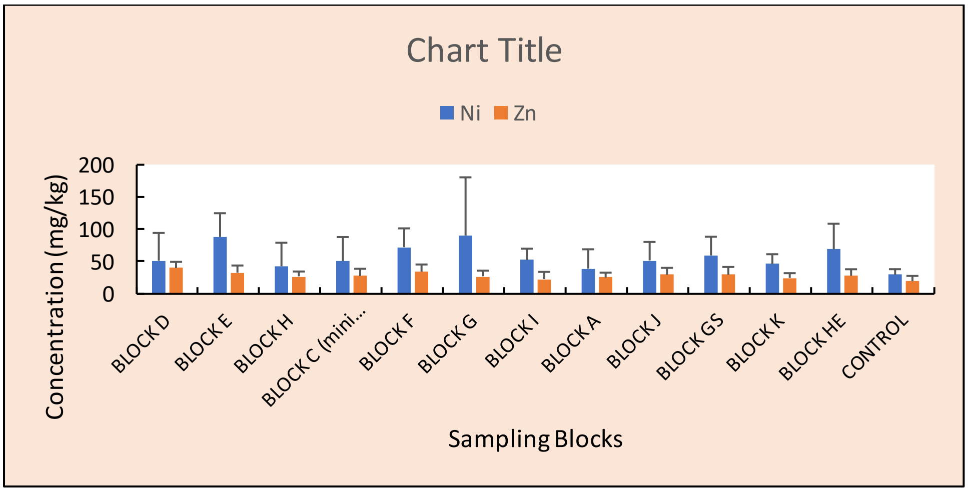


Figure 4.8.11: Nickel and Zinc levels in sediments of the study area compared with control during the dry season

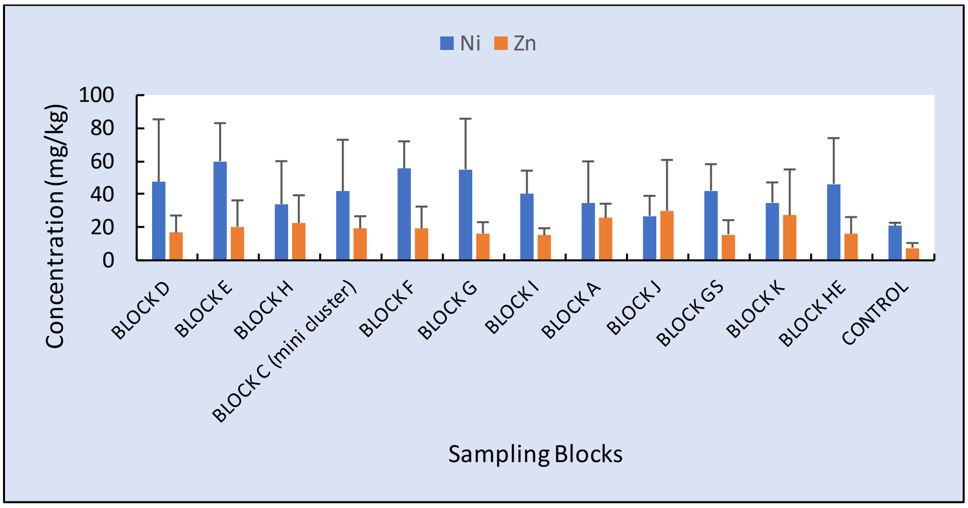


Figure 4.8.12: Nickel and Zinc levels in sediments of the study area compared with control during the wet season

Zinc ranged from 0.322 to 98.784 mg/kg in the study locations and from 3.911 to 30.125 mg/kg at the controls (Figure 4.8.11 and 4.8.12). There was no significant seasonal variation but levels at study location were significantly higher than control during the dry season. Zinc levels are low and well within background levels of 1-76 mg/kg for the Niger Delta area or the ERL of 150 mg/kg as well as the DPR target limit of 140 mg/kg.

Lead ranged from 0.124 to 5.803 mg/kg at the study locations and from 3.021 to 21.741 mg/kg at the control locations (Figure 4.8.13 and 4.8.14). Values were higher at controls than study locations and during dry season compared to wet season. All values were within historical measurements in the Niger Delta sediments BDL-37 mg/kg), the NOAA-ERL of 47 mg/kg and the DPR target limit 85 mg/kg.

Copper ranged from 2.118 to 16.133 mg/kg at the study locations and from 0.352 to 4.403 mg/kg at control locations (Figure 4.8.13 and 4.8.14). Copper showed significantly higher levels at study locations compared to control and during the dry compared to wet season. All values were however within the NOAA-ERL of 34 mg/kg and the DPR target of 36 mg/kg.

Chromium ranged from 0.209 to 59.167 mg/kg at the project locations and from 8.927 to 26.235 mg/kg with significantly higher values at study locations and during the dry than wet season (Figure 4.8.13 and 4.8.14). Obtained values of chromium were higher than baseline measurement in the Niger Delta sediments of BDL-8 mg/kg but well within the NOAA-ERL of 81 mg/kg and DPR target limit of 100 mg/kg.

Cadmium ranged from 0.238 to 13.258 at the project locations and from 2.191-3.245 mg/kg at the controls (Figure 4.8.13 and 4.8.14). Values were significantly higher at study locations than control and during the dry compared to wet season. A number of values at the project locations were higher than the background levels for the Niger Delta sediment of BDL-8 mg/kg, the NOAA-ERM of 9.6 mg/kg and the DPR intervention limit of 12 mg/kg indicating high cadmium contamination in the project area. The most significant use of cadmium is in nickel/cadmium batteries. Cadmium coatings provide good corrosion resistance, particularly in high stress environments such as marine but the coating is preferentially corroded if damaged. Cadmium finds other uses in pigments, stabilisers for PVC, in alloys and electronic compounds. Cadmium is also present as an impurity in several products, including phosphate fertilisers, detergents and refined petroleum products and as such reach the environment from many point and non-point sources.

Barium ranged from 5 to 16 mg/kg at the project locations and from 8 to 17 mg/kg at the control (Figure 4.4.13 and 4.4.14). There were no significant differences between study location and controls and between wet and dry season.

Cobalt ranged from 4.231 to 19.124 at the project locations and from 10.235 to 20.123 mg/kg at the controls (Figure 4.4.13 and 4.4.14). Cobalt was significantly higher at controls than study locations and during the dry compared to wet season. Values were generally within the DPR target limit of 20 mg/kg indication uncontaminated environment.

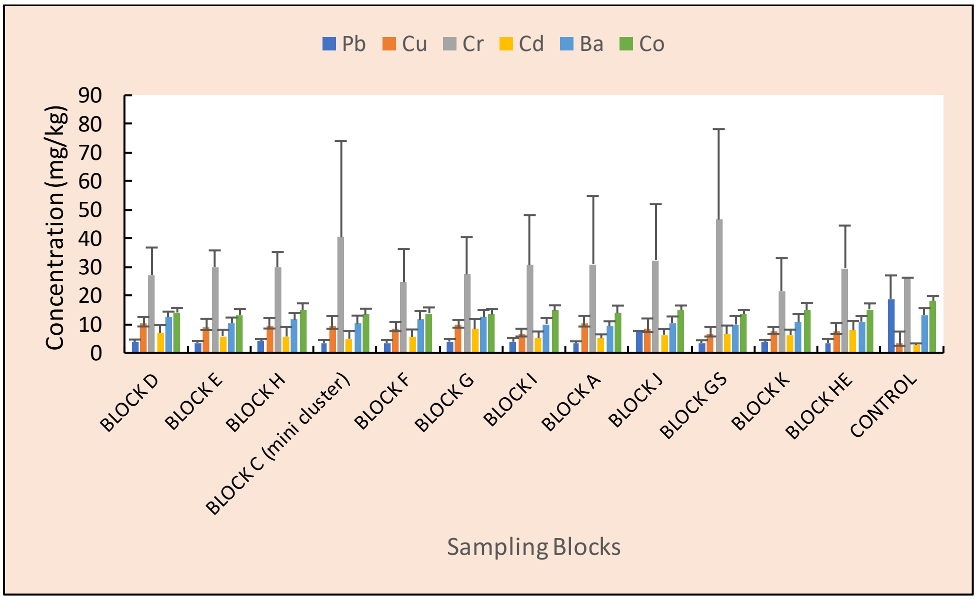


Figure 4.8.13: Heavy metal levels in sediments of the study area compared with control during the dry season

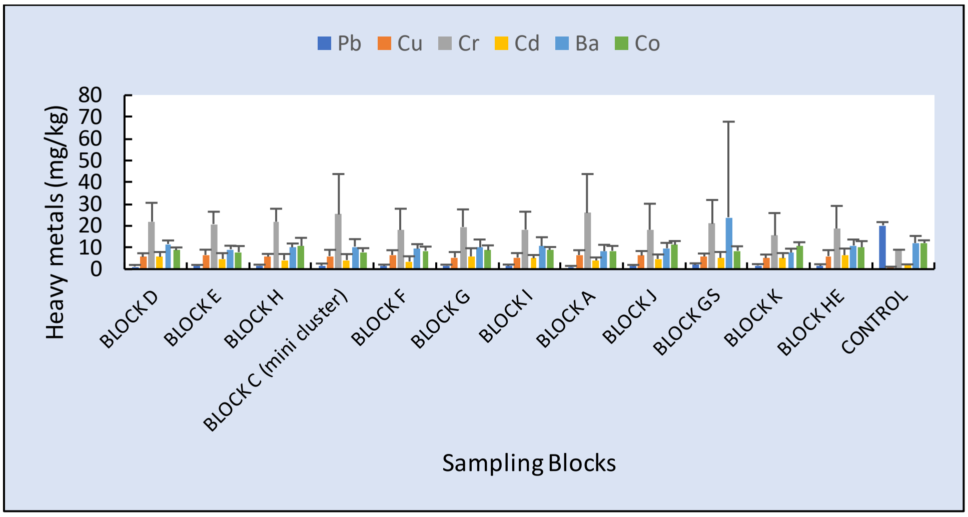


Figure 4.8.14: Heavy metal levels in sediments of the study area compared with control during the wet season

Hydrocarbons: Polycyclic aromatic hydrocarbons and BTEX were not detected in the sediments. Total hydrocarbons (THC) ranged from 5.7 to 22.5 mg/kg at the study locations and from 6.3 to 17 mg/kg at the controls with no significant difference between study locations and controls. Wet season was significantly higher than dry season at the study locations.

Total Petroleum Hydrocarbons (TPH) ranged from 0.03 to 11 mg/kg at the study locations and from 0 to 0.02 mg/kg at the controls. Massoud, *et al*., (1996) reports a robust classification scheme for TPH in sediments which has been used in the Persian Gulf. The total petroleum hydrocarbons (TPH) concentration in the Persian Gulf sediments was categorized into four levels with levels in Unpolluted area/natural background being 10-15 ppm. The measured levels of TPH in the JK field are within normal unpolluted levels. The levels are also within the DPR target for mineral hydrocarbons of 50 mg/kg.

Sediment Microbiology: The microbial community of the JK sediments showed very sparse density at all seasons. Hydrocarbon Utilizing Fungi was not present during the dry season showed very low counts during the wet season ranging from 0.2 to 33 cfu/g at the study location and from 3-4 cfu/g at the control. Hydrocarbon Utilizing Bacteria (HUB) ranged from 0.1 to 24 cfu/g at study locations and from 0 to 2.2 cfu/g at the controls. Very low counts to absence of hydrocarbon utilizing fungi and bacteria are indicators of petroleum unpolluted environments.

Total Heterotrophic Bacteria (THB) ranged from 6 to 22 at the study locations and from 9 to 92 cfu/g at the controls with no significant difference between study location and controls and between seasons. Total Heterotrophic Fungi (THF) ranged from 6 to 97 cfu/g at the study locations and from 9 to 92 cfu/g at the controls. THF was significantly higher during the wet season compared to dry season. The THB and TF counts were also quite low compared to normal levels in sediments which can reach 10^9 to 10^{10} counts/cm3 of sediment. The low counts of bacteria and fungi may be attributed to low levels of organic carbon in the sediments. On the other hand, Sulphur Reducing Bacterial counts were relatively high. Sulphur Reducing Bacteria (SRB) was only obtained only during the wet season and ranged from 3-88 x 10^5 cfu/g at the study location and from 5.1-44 x 10^5 cfu/g at the controls. Under the observed reducing conditions of the sediment, SRB are known to play important roles in the degradation of organic matter, obtaining the needed energy through reduction of sulphate to sulphide (Colman and Holand, 2000).

4.9: Hydrobiology

4.9.1: Phytoplankton Composition

The Phytoplankton checklist and detailed composition from the JK field are shown in Table 4.9.1 and detailed in Appendix 8.0 respectively. The phytoplankton was composed of 24 species distributed in 17 families, 9 orders, and 2 classes namely the Bacillariophyceae and the Dinophyceae. The phytoplankton was dominated by Bacillariophyceae with 23 species making 94.73%, while the Dinophyceae was represented by 1 species making 5.26%. Phytoplankton distribution in the control area was represented by 12 species in 4 Classes namely Bacillariophyceae (40.74%), Dinophyceae (38.89%), Fragillariophyceae (15.74%) and Haptophyceae (4.63%) with Dinophyceae being the most dominant followed by the Bacillariophyceae and the Fragillariophyceae and Haptophyceae (Figure 4.9.1). The Bacillariophyceae was represented by 4 species while the Dinophyceae recorded 6 species. The Fragillariophyceae and Haptophyceae recorded only 1 species each.

Table 4.9.1: Checklist of Phytoplankton in the JK Field.

S/N	Species	Family	Order	Class
1	*Coscinodiscus centralis*	Coscinodiscaceae	Coscinodiscales	Bacillariophyceae
2	*Coscinodiscus minor*	Coscinodiscaceae	Coscinodiscales	Bacillariophyceae
3	*Cosmioneis sp.*	Cosmioneidaceae	Naviculales	Bacillariophyceae
4	*Cyclotella spp*	Stephanodiscaceae	Thalassiosirales	Bacillariophyceae
5	*Craticula sp.*	Stauroneidaceae	Naviculales	Bacillariophyceae
6	*Diatoma sp.*	Fragilariaceae	Fragilariales	Bacillariophyceae
7	*Diploneis vagabuda*	Diploneidaceae	Naviculales	Bacillariophyceae
8	*Entomoneis sp.*	Entomoneidaceae	Surirellales	Bacillariophyceae
9	*Grammatophora marina*	Striatellaceae	Striatellales	Bacillariophyceae
10	*Gyrosigma balticum*	Pleurosigmataceae	Naviculales	Bacillariophyceae
11	*Gyrosigma peisonis*	Pleurosigmataceae	Naviculales	Bacillariophyceae
12	*Mastogloia exilis*	Mastogloiaceae	Mastogloiales	Bacillariophyceae
13	*Mastogloia paradoxa*	Mastogloiaceae	Mastogloiales	Bacillariophyceae
14	*Navicula spp.*	Naviculaceae	Naviculales	Bacillariophyceae

S/N	Species	Family	Order	Class
15	*Nitzchia spectabilis*	Bacillariaceae	Bacillariales	Bacillariophyceae
16	*Nitzchia nitzcloidea*	Bacillariaceae	Bacillariales	Bacillariophyceae
17	*Oestrupia zanardiniana*	Bacillariophyceae	Naviculales	Bacillariophyceae
18	*Pleurosigma spp.*	Pleurosigmatacea e	Naviculales	Bacillariophyceae
19	*Pseudonitzchia spp.*	Bacillariaceae	Bacillariales	Bacillariophyceae
20	*Rhabdonema punctatum*	Pinnulariaceae	Naviculales	Bacillariophyceae
21	*Skeletonema sp.*	Skeletonemaceae	Thalassiosirale s	Bacillariophyceae
22	*Synedra spp.*	Fragilariaceae	Fragilariales	Bacillariophyceae
23	*Surirella fastuosa*	Surirellaceae	Surirellales	Bacillariophyceae
24	*Prorocentrium spp.*	Prorocentraceae	Prorocentrales	Dinophyceae

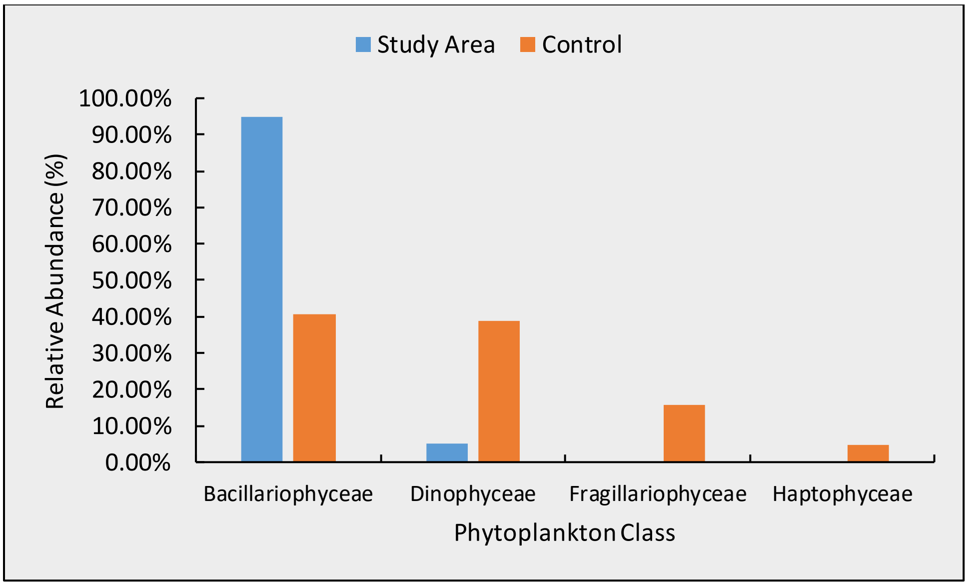


Figure 4.9.1: Distribution of phytoplankton in JK field during present study

Table 4.9.2 shows the ecological indices of phytoplankton from the JK field. Species number ranged from 7 to 23 at the project area and from 9 to 12 at the control. Species density ranged from 40 to 324 cells/l at the project location and from 54 to 76 cells/l at the control showing higher densities in some stations of the project area compared to the control. Diversity as measured by the Shannon index ranged from 1.65 to 2.195 at the project location compared to the control which ranged from 1.963 to 2.97 with no significant difference between the study location and control. Similarly, the Margalef index ranged from 1.33 to 3.806 at the project area compared to 1.847 to 2.645 at the control with no significant difference between the study location and control. The Shannon index increases as both the richness and the evenness of the community increase. Typical values are generally between 1.5 and 3.5 in most ecological studies, and the index is rarely greater than 4. In Shannon Wiener legislation, the aquatic environment is classified as – very good when H´ is > 4, good quality 4- 3, moderate quality 3-2, poor quality 2-1 and very poor quality <1. A community becomes more dissimilar as the stress increases and accordingly species diversity decreases with poor water quality. A community dominated by relatively few species indicates environmental stress (Plafkin *et al*., 1989). From the forgoing, both the project area and control may be classified as stressed environments (Shannon between 1 and 3) with a poor to moderate quality but the control was relatively better than the study location.

Table 4.9.2: Ecological indices of the Phytoplankton in JK field during the present study

	Study Area				Control			
Biological Indices	Min	Max	Mean	STD	Min	Max	Mean	STD
Species Number	7	23	11.78947	2.95	9	12	10.33333	1.25
Density (cells/l)	40	324	144.2	57.04	54	76	64.66667	8.99
Dominance_D	0.1956	0.2327	0.211812	0.01	0.1392	0.1763	0.1631	0.02
Simpson_1-D	0.7673	0.8044	0.788188	0.01	0.8237	0.8608	0.8369	0.02
Shannon_H	1.65	2.195	1.900316	0.11	1.963	2.17	2.044333	0.09
Evenness_e^H/S	0.3905	0.8194	0.589431	0.08	0.7295	0.7914	0.7532	0.03
Brillouin	1.461	2.074	1.761484	0.12	1.75	1.915	1.815	0.07
Menhinick	0.7338	1.278	0.997512	0.12	1.032	1.5	1.297667	0.20
Margalef	1.33	3.806	2.177842	0.44	1.847	2.645	2.249333	0.33
Equitability_J	0.7001	0.8976	0.782712	0.04	0.8685	0.8935	0.878367	0.01
Fisher_alpha	1.767	5.658	3.080884	0.69	2.656	4.36	3.542	0.70
Berger-Parker	0.3012	0.3485	0.317705	0.01	0.2344	0.3333	0.2945	0.04
Chao-1	7	23	11.9	2.99	9	12.25	10.49	1.36

Seasonal variation of phytoplankton in the JK field

Table 4.9.3 shows the distribution of phytoplankton in the JK field in the dry season compared to the wet season. Marked variations were found in the phytoplankton distribution in 2018 compared to 2019 which could be attributed to seasonal and locational differences in sampling strategy. Although the Bacillariophyceae remained dominant in both years, some species which occurred in 2018 such as Cyanophyceae and Euglenophyceae were absent in 2019 studies while new species such as Haptophyceae and Fragillariophyceae were enumerated at the project location during 2019. Similar changes were also recorded at the controls. The diversity of phytoplankton was significantly higher during 2018 compared to 2019 at both the project locations and control signifying a more stressful environment during the 2019 studies. Phytoplankton displays usually a patchy distribution which are susceptible to changes with the general dynamics of the water as well as with water quality variations.

Table 4.9.3: Season variation of phytoplanktons in the JK field

Area	Composition		Diversity	
	Dry season (2018)	**Wet season (2019)**	**Dry season (2018)**	**Wet season (2019)**
Study Area	✓ Bacillariophycea ✓ Chlorophyceae, ✓ Cyanophyceae, ✓ Dinophyceae ✓ Euglenophyceae.	✓ Bacillariophyceae ✓ Dinophyceae ✓ Fragilariophyceae ✓ Haptophyceae ✓ Dictyochophyceae	Margalef's index: 6.64-9.61	Margalef's index: 1.33-3.806
Control	✓ Bacillariophycea ✓ Cyanophyceae ✓ Chlorophyceae ✓ Dinophyceae ✓ Euglenophyceae	✓ Bacillariophycea ✓ Dinophyceae ✓ Fragilariophyceae ✓ Haptophyceae.	Margalef's index: 3.15-3.29	Margalef's index: 1.847-2.645

4.9.2: Zooplankton composition of the JK Field

The checklist of Zooplankton community from the JK field is presented in Table 4.9.4. Detailed results are presented in Appendix 8.0. The zooplankton was represented by a total of 21 species belonging to 10 orders and 7 Classes. The control recorded 11 species in 3 classes. The order of dominance was Hexanauplia (12 species, 60.74%)> Oligotrichea (4 species, 10.77%)> Malacostraca (3 species, 7.74%)> Stenolaemata, Polycheata, Branchiopoda and Calanoida (all having 1 species each). For the control, the order of dominace was Hexanauplia (6 species,69.66%)> Oligotrichea (4 species, 19.10%)> Stenolaemata (1 species,11.24%). Polycheata, Malacostraca, Branchiopoda and Calanoida were absent in the control points (Figure 4.9.2).

Table 4.9.4: Checklist of Zooplankton in the JK Field

S/N	Species	Family	Order	Class
1	*Aegisthus mucronatus*	*Aegisthidae*	*Harpacticoida*	Hexanauplia
2	*Acartia tonsa*	*Acartiidae*	*Calanoida*	Hexanauplia
3	*Acrocalanus longicornis*	*Paracalanidae*	*Calanoida*	Hexanauplia
4	*Elminius modestus (Nauplius)*	*Austrobalanidae*	*Sessilia*	Hexanauplia
5	*Bestiolina Arabica*	*Paracalanidae*	*Calanoida*	Hexanauplia
6	*Semibalanus balanoides (larvae)*	*Archaeobalanidae*	*Sessilia*	Hexanauplia
7	*Canthocalanus pauper*	*Calanidae*	*Calanoida*	Hexanauplia
8	*Calanopia elliptica*	*Pontellidae*	*Calanoida*	Hexanauplia
9	*Euchaeta concinna*	*Euchaetidae*	*Calanoida*	Hexanauplia
10	*Ambunguipes spp.*	*Hamondiidae*	*Harpacticoida*	Hexanauplia
11	*Oithona nana*	*Oithonidae*	*Cyclopoida*	Hexanauplia

S/N	Species	Family	Order	Class
12	*Oithona setigera*	*Oithonidae*	*Cyclopoida*	Hexanauplia
13	*Strobilidium sp*	*Strobilidiidae*	*Choreotrichida*	Oligotrichea
14	*Tintinnus sp*	*Tintinnidae*	*Choreotrichida*	Oligotrichea
15	*Tintinnopsis sp.*	*Codonellidae*	*Choreotrichida*	Oligotrichea
16	*Euphausia recurve*	*Euphausiidae*	*Euphausiacea*	Malacostraca
17	*Alpheus sp. (nauplius)*	*Alpheidae*	*Decapoda*	Malacostraca
18	*Tomopteris spp.*	*Tomopteridae*	*Phyllodocida*	Polychaeta
19	*Actinopora sp.*	*Actinoporidae*	*Cyclostomatida*	Stenolaemata
20	*Daphnia sp.*	*Daphniidae*	*Anomopoda*	Branchiopoda
21	*Calanoides spp.*	*Calanidae*	*Calanoida*	Calanoida

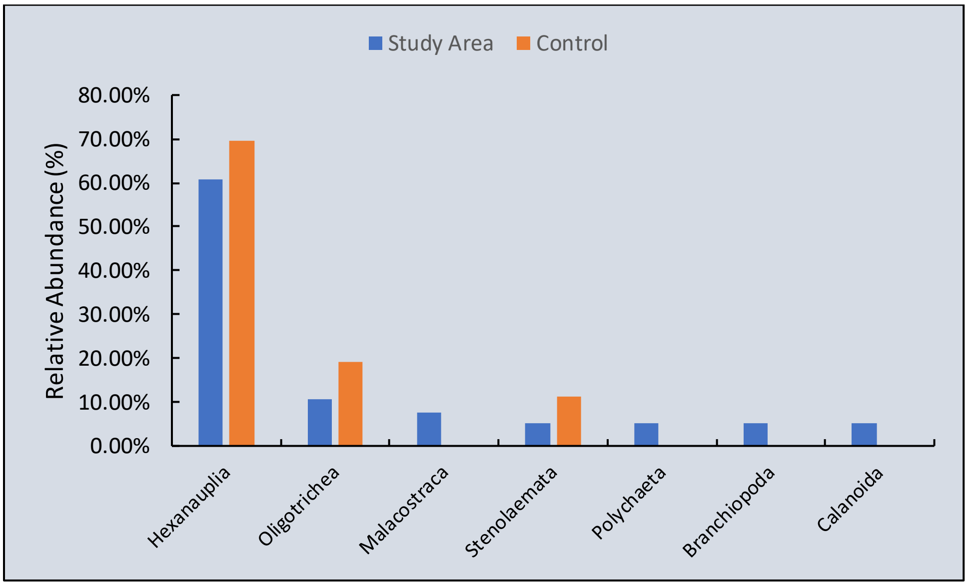


Figure 4.9.2: Distribution of Zooplankton in the JK field compared with control

Table 4.9.5 shows the ecological indices of zooplankton from the JK field. Species number ranged from 3 to 17 at the project area and from 4 to 8 at the control. Species density ranged from 10 to 88 organisms/l at the project location and from 17 to 43 organisms/l at the control showing higher densities in some stations of the project area compared to the control. Diversity as measured by the Shannon index ranged from 1.01 to 2.717 at the project location compared to the control which ranged from 1.32 to 2.05 with higher values at the study location compared to control. Similarly, the Margalef index ranged from 0.6569 to 3.695 at the project area compared to 0.8909 to 1.861 showed higher values at the study locations. The Shannon index (H´) increases as both the richness and the evenness of the community increase. Typical values are generally between 1.5 and 3.5 in most ecological studies. In Shannon Wiener legislation, the aquatic environment is classified as – very good when H´ is > 4, good quality 4- 3, moderate quality 3-2, poor quality 2-1 and very poor quality <1. A community becomes more dissimilar as the stress increases and accordingly species diversity decreases with poor water quality (Plafkin *et al*., 1989). From the forgoing, both the project area and control may be classified as stressed environments (Shannon between 1 and 3) with a poor to moderate water quality but the study location was relatively of higher quality than the control.

Table 4.9.5: Summary of Ecological indices of the Zooplankton in JK field during the present study

	Study Area				Control			
Ecological Index	Min	Max	Mean	STD	Min	Max	Mean	STD
Species Number	3	17	7	2.68	4	8	5	1.89
Density (organisms/l)	10	88	35	14.48	17	43	29	10.62
Dominance_D	0.07202	0.385	0.177874	0.06	0.1325	0.2803	0.228367	0.07
Simpson_1-D	0.615	0.928	0.822127	0.06	0.7197	0.8675	0.771633	0.07
Shannon_H	1.01	2.717	1.860347	0.35	1.32	2.05	1.569667	0.34
Evenness_e^H/S	0.6917	0.9811	0.907821	0.05	0.9356	0.9713	0.9535	0.01
Brillouin	0.8055	2.394	1.588289	0.34	1.075	1.788	1.343333	0.32
Menhinick	0.6547	1.95	1.25676	0.24	0.7428	1.22	0.977633	0.19
Margalef	0.6569	3.695	1.819237	0.56	0.8909	1.861	1.2703	0.42
Equitability_J	0.7943	0.9902	0.949355	0.03	0.952	0.986	0.9679	0.01
Fisher_alpha	0.9578	6.802	2.9787	1.06	1.258	2.895	1.934	0.70
Berger-Parker	0.1023	0.4615	0.239682	0.08	0.186	0.3529	0.294567	0.08
Chao-1	3	17	7.60	2.71	4	8	5.33	1.89

Seasonal variation of Zooplanktons in the JK field.

Table 4.9.6 shows the distribution of Zooplankton in the JK field in 2018 compared to present study in 2019. The species diversity and dominance pattern were completely different between both studies. Species enumerated in 2019 were all absent in the 2018 studies. The observed differences may be attributed to seasonal and locational differences in sampling strategy. The diversity of zooplankton was significantly higher during 2018 compared to 2019 at both the project locations and control signifying a more stressful environment during the 2019 studies. Phytoplankton distribution are susceptible to changes with the general dynamics of the water as well as with water quality variations both of which can change dramatically with season.

Table 4.9.6: Season variation of zooplanktons in the JK field

Area	Composition		Diversity	
	Dry season (2018)	**Wet season (2019)**	**Dry season (2018)**	**Wet season (2019)**
Study Area	✓ Rotifers ✓ Copepods ✓ Cladocera ✓ Molluscs ✓ Decapods ✓ Euphausids	✓ Hexanauplia ✓ Oligotrichea ✓ Malacostraca ✓ Stenolaemata ✓ Polycheata ✓ Branchiopoda ✓ Calanoida	Margalef's index: 1.84-3.09	Margalef's index: 0.6769-1.8192
Control	✓ Rotifers ✓ Copepods ✓ Cladocera ✓ Molluscs ✓ Decapods ✓ Euphausids	✓ Hexanauplia ✓ Oligotrichea ✓ Stenolaemata	Margalef's index: 3.38-6.95	Margalef's index: 0.8909-1.861

4.9.3: Macro Benthos composition of the JK Field

Macrobenthic invertebrates are useful bio-indicators providing a more accurate understanding of changing aquatic conditions than chemical and microbiological data, which at least give short-term fluctuations (Ravera, 1998, 2000; Ikomi *et al*., 2005).

Benthic Fauna Composition

The Checklist of Benthic fauna in the JK field is presented in Table 4.9.7. Detailed result of benthic studies are presented in Appendix 8.0. Benthic fauna from the S locations were composed of 26 species distributed in 16 families, 10 orders, and 2 classes namely Bivalvia and Gastropoda. The fauna was dominated by Gastropoda (21 species) followed by Bivalvia (4 species). The control was similarly occupied by Gastropods (10 species) followed by Bivalves (5 species). Wide spatial variations were recorded in species distribution of the Gastropods but Bivalves were quite similar in their species distribution except *Chlamy opercularis* which was absent in several samples. Variations are attributable to restriction of habitats and niches by physical and/or chemical factors (UNESCO/WHO/UNEP, 1966).

Table 4.9.7: Checklist of Benthic Fauna in the JK Field during the present study

SN	Benthos Species	Family	Order	Class
1	*Cornus marmoreus*	Conidae	Neogastropoda	Gastropoda
2	*Turritella cingulifera*	Turritellidae	Caenogastropoda	Gastropoda
3	*Margarites helicinus*	Margaritidae	Trochida	Gastropoda
4	*Vokesimurex elenensis*	Muricidae	Neogastropoda	Gastropoda
5	*Genota mitriformis*	Borsoniidae	Neogastropoda	Gastropoda
6	*Stigmaulax elenae*	Naticidae	Littorinimorpha	Gastropoda

SN	Benthos Species	Family	Order	Class
7	*Ptychosyrinx sp*	Turridae	Neogastropoda	Gastropoda
8	*Neptunea ventricosa*	Buccinidae	Neogastropoda	Gastropoda
9	*Ptychosyrinx sp*	Turridae	Neogastropoda	Gastropoda
10	*Eucithara dubiosa*	Mangeliidae	Neogastropoda	Gastropoda
11	*Glyphoturris rugirima*	Mangeliidae	Neogastropoda	Gastropoda
12	*Heterocithora sp.*	Mangeliidae	Neogastropoda	Gastropoda
13	*Bathytoma neocaledonica*	Borsoniidae	Neogastropoda	Gastropoda
14	*Oenopota uschakovi*	Mangeliidae	Neogastropoda	Gastropoda
15	*Genota mitriformis*	Borsoniidae	Neogastropoda	Gastropoda
16	*Aporhais spp*	Aporrhaidae	Littorinimorpha	Gastropoda
17	*Turritella incrasata*	Turritellidae	Caenogastropoda	Gastropoda
18	*Gemmula rarimaculata*	Turridae	Neogastropoda	Gastropoda
19	*Cryplogemma corneus*	Turridae	Neogastropoda	Gastropoda
20	*Comarmondia gracilis*	Clathurellidae	Neogastropoda	Gastropoda
21	*Eucithara amabilis*	Mangeliidae	Neogastropoda	Gastropoda
22	*Neptunea antiqua*	Buccinidae	Neogastropoda	Gastropoda
23	*Bursa sp*	Bursidae	Littorinimorpha	Gastropoda
24	*Ophiodermella inermis*	Borsoniidae	Neogastropoda	Gastropoda
25	*Bela atlantidea*	Mangeliidae	Neogastropoda	Gastropoda
26	*Colopsira sp*	Turritellidae	Caenogastropoda	Gastropoda
27	*Amalda vernedev*	Ancillariidae	Neogastropoda	Gastropoda
28	*Genota sp*	Borsoniidae	Neogastropoda	Gastropoda
29	*Eucithara abbreviata*	Mangeliidae	Neogastropoda	Gastropoda
30	*Aequipecten opercularis*	Pectinidae	Pectinida	Bivalvia
31	*Chlamy opercularis*	Pectinidae	Pectinida	Bivalvia
32	*Mya arenaria*	Myidae	Myida	Bivalvia
33	*Mercenaria mercenaria*	Veneridae	Venerida	Bivalvia
34	*Cerastoderma glaucum*	Cardiidae	Cardiida	Bivalvia

In all the sampling strata, Bivalves showed higher abundance compared to Gastropods (Figure 4.9.3). A similar trend was observed at the control locations with Bivalves recording 92.25% against Gastropods at 7.48% except at Control station 3 where benthos was not observed.

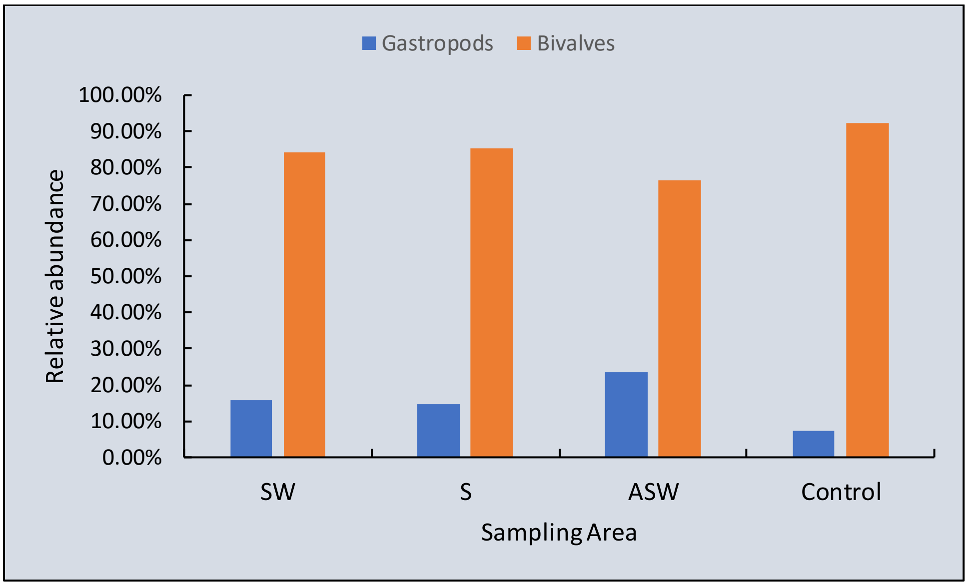


Figure 4.9.3: Distribution of benthic fauna in the JK field compared with control

Table 4.9.8 shows the ecological indices of benthic of macro benthos from the JK field. Species number ranged from 1 to 17 at the project area and from 1 to 10 at the control. Species density ranged from 13 to 131 organisms/m^2 at the project location and from 1 to 38 organisms/m^2 at the control showing higher densities in some stations of the project area compared to the control. Diversity as measured by the Shannon index ranged from 0 to 2.327 at the project location compared to the control which ranged from 9 to 1.993 showing higher values at the study location compared to control. Similarly, the Margalef index ranged from 0 to 3.766 at the project area compared to 0 to 2.474 at the control with significantly higher values at the study locations. The Shannon index increases as both the richness and the evenness of the community increase. Typical values are generally between 1.5 and 3.5 in most ecological studies, and the index is rarely greater than 4. In Shannon Wiener legislation, the aquatic environment is classified as – very good when H´ is > 4, good quality 4- 3, moderate quality 3-2, poor quality 2-1 and very poor quality <1. A community becomes more dissimilar as the stress increases and accordingly species diversity decreases with poor water quality (Plafkin *et al*., 1989). From the forgoing, both the project area and control may be classified as stressed environments (Shannon between 0 and 3+) with a poor to moderate sediment quality but the the study location was relatively of higher quality than the control.

Table 4.9.8: Summary of Ecological indices of the Benthic fauna in JK field during the present study

Ecological Index	SW				S				ASW				Control			
	Min	Max	Mean	STD	Min	Max	Mean	STD	Min	Max	Mean	STD	Min	Max	Mean	STD
Species Number	3	17	6	3.04	5	14	8	2.19	1	9	6	1.96	1	10	6	3.74
Density (Organisms/m2)	13	77	37	15.54	16	131	60	21.49	20	63	43	12.61	1	38	24	16.58
Dominance_D	0.1339	0.8272	0.3728	0.17	0.1356	0.3516	0.2363	0.06	0.1882	1	0.3613	0.16	0.1717	1	0.4528	0.39
Simpson_1-D	0.1728	0.8661	0.6271	0.17	0.6484	0.8644	0.7636	0.06	0	0.8118	0.6386	0.16	0	0.8283	0.5471	0.39
Shannon_H	0.3965	2.327	1.3191	0.44	1.304	2.193	1.6751	0.24	0	1.909	1.2998	0.39	0	1.993	1.2556	0.89
Evenness_e^H/S	0.3716	0.9776	0.6399	0.14	0.4726	0.8033	0.680	0.08	0.5105	1	0.6700	0.11	0.734	1	0.8587	0.11
Brillouin	0.3326	2.028	1.1122	0.37	1.074	1.938	1.4831	0.22	0	1.485	1.1294	0.33	0	1.681	1.06633	0.76
Menhinick	0.3873	2.032	1.1030	0.42	0.6455	1.75	1.0966	0.31	0.2	1.964	0.932	0.35	1	1.622	1.274	0.26
Margalef	0.4885	3.766	1.5522	0.75	0.977	3.04	1.7857	0.51	0	2.628	1.3419	0.55	0	2.474	1.3916	1.03
Equitability_J	0.286	0.9859	0.7255	0.15	0.6745	0.8788	0.8103	0.06	0.5823	0.8787	0.7552	0.08	0.8657	0.9117	0.8887	0.02
Fisher_alpha	0.6646	7.145	2.5624	1.56	1.297	5.184	2.7601	1.06	0.2085	5.966	2.0679	1.12	0	4.423	2.3653	1.82
Berger-Parker	0.2571	0.9074	0.5093	0.18	0.2069	0.5625	0.3533	0.09	0.2895	1	0.4955	0.15	0.2647	1	0.5268	0.34
Chao-1	3	37.5	9.48	7.74	5	15.5	9.43	2.92	1	14	6.85	3.07	1	11	6.33	4.11

Seasonal variation of Benthic fauna community in the JK field

Table 4.9.9 shows the distribution of benthic fauna in the JK field in 2018 compared to present study in 2019. The species diversity and dominance pattern were completely different between both studies. Species enumerated in 2019 represented a very small fraction of those present in the 2018 studies. The observed differences may be attributed to seasonal and locational differences in sampling strategy. The diversity of benthos was significantly higher during 2018 compared to 2019 at both the project locations and control signifying a more stressful environment during the 2019 studies. Benthos distribution are susceptible to changes with the general dynamics of the water as well as with sediment quality variations both of which can change dramatically with seasons.

Table 4.9.9: Trending in Benthic fauna Community between 2018 and 2019

Area	Composition		Relative Abundance	
	Dry season (2018)	**Wet season (2019)**	**Dry season (2018)**	**Wet season (2019)**
Study Area	6 classes ✓ Polychaetes ✓ Crustaceans ✓ Bivalves ✓ Gastropod ✓ Molluscs ✓ Insects Pisces. 19 species	2 classes ✓ Bivalves ✓ Gastropods S= 26 species; ASW= 21 species SW= 24 species	Most Abundant Polychaetes (51%)	Most Abundant Bivalves (81.72%)
Control	7 classes ✓ Polychaetes ✓ Crustaceans ✓ Bivalves ✓ Gastropod ✓ Molluscs ✓ Insects ✓ Pisces.	2 classes ✓ Bivalves ✓ Gastropods	Crustaceans (43%)	Bivalves (82,5%)

Plate 4.10.1a: Benthic composition of the JK field

4.10: Fisheries Studies

Fishing Activities

Artisanal fishers operate largely in rivers creeks and creeklets that empty directly or indirectly into the Atlantic Ocean adjacent to the project area. These rivers, creeks and creeklets include Akwamobugo creek and Brass River, into which the former empties, Akassa creek, Ekole Creek, Nembe Creek and St. Nicholas River. Fishers with motorised wooden boats operate in the near shore shallow ocean area. Information from the baseline study further reported that other fishers operate in dug-out wooden canoes which may or may not be motorized. In the Akuku-Toru axis where the Sombrero river and its network of creeks traverses (Ibim and Bongilli, 2017,2018; Ibim and Douglas, 2016) the project area, the fishers are also predominantly artisanal fishers depending on planked wooden boats that may or may not be motorized (Plate 4.10.1).

Plate 4.10.1b: Small fishing activity around the project area (a &b)

Fishing Gears

Fishing in in the project area is a multi – fishing gears operation. The fishing gears used were ghost shrimp traps, castnets, gillnets, setnets, long line, Stownet, scoopnet and circular liftnets. The gillnets and setnets measure 6-12 m in length and 2-4 meters in width. Nets are manually operated using paddles and poles. They are set and allowed to stay for up to one hour before they are retrieved with the catch. The fishermen in this area go fishing with more than one net units. When the net is set and before it is removed another net is also set. Other fishing gears used especially by the female fishers in the fin or shell fishery are traps, mainly the basket traps and the non-return valve traps. The non-return valves are set in shallow areas of the rivers on stakes and in creeks where they catch fishes swimming with the tide or seeking for food set as traps in the traps. Also, the women fishers pick the shell fishes with baskets.

Life Expectancy of Fishing Gears

Monofilament nets are considered very effective when in use because they are thin, but their durability is short. Fishermen engaged in catching juveniles prefer to use them. The nets often snap whenever fish is being extracted and only floats, sinkers, and the ropes are recoverable for possible recycling. They last for only 3 to 12 months depending on intensity of fishing and the fishing ground. Stownet can last between 6 months and 2 years depending on the mending ability of the fisherfolk. The traps used in the area last between 1 to 2 years depending on the use intensity and maintenance.

Fishing Intensity

The fishing operation depends on the fishing weather (calmness and roughness) and the number of crew also is dependent on the system and species targeted. For small operations between 1 – 3 crew (comprising man, wife and son or man and son or two women) are involved. In some fishing settlements the crew pool to share facilities such as boat and engine, with individual fishermen bringing in their own net. Although this is not common among the fishers in the project area. The boat owner can carry more than one net. The outboard engine owner also enjoys the same status as the boat owner. All fishermen own a combination of gears to be able to fish all the year round and they take advantage of the proximity of the sea. The fishing days vary between 5 and 7 days a week.

Fish Catch

The catch rates were previously reported to be dependent on seasons (Emmanuel, 2009). The fishers catch more in the dry season than in the wet season. This was attributed to ease of fishing, low water volume and concentration of fishes in smaller areas in the dry season (Ibim and Njoku, 2018). Fish catches from these rivers are sold in settlement such as Kulama, Sangana, Brass, Nembe, Odiama, Degema, Abonnema and Yenagoa. Fish sales vary from N1000.00 to N100,000.00 daily depending on the season and the catch. However, the demand outstrips the supply.

Fish Composition

The fish composition of the area was reported based on literature. Information was obtained from the work of Troadec and Garcia (1980) on the fish species that inhabit the coastal waters of Nigeria. They reported several species fished by off-shore trawlers such as Lutjanidae, Sparidae, Serranidae Cynoglossidae Ariidae Pomadasyidae, Haemulidae, Polynemidae, and Rajidae. Also, the Baseline studies (2018) reported some fishes targeted by artisanal fishers in the area. These Fish stocks were: croakers (*Pseudotolithus*), threadfins (*Galeoides, Pentanemus* and *Polydactylus*), soles (Cynoglossidae), marine catfish (*Arius*), brackish water catfish (*Chrysichthys*), snapper (*Lutjanus*), grunts (Pomadasyidae), groupers (*Epinephelus*), and the estuarine white shrimp (*Palaemon*). Bonga dominates the pelagic fishery but there are modest catches of shad (*Ilisha*), sardine (*Sardinella*), various jacks (*Caranx spp*.) and Atlantic bumper (*Chloroscombrus chrysurus*).

Furthermore, Fish fauna of the area was reported by Ibim and Bongilli (2018) from a total catch of 40,509 fish specimens in 24 weeks of study of the Sombrero River. They reported a total 31 species belonging to 26 genera, 20 families and 10 orders. The Carangidae was the highest with four species (*Trachinotus teraia, Carangoides malabaricus, Alectis indica, Caranx hippos*) in four (4) genera and 13 out of the 31species, the Scombridae (*Scomberomorous tritor*), Belonidae (*Tylosurus acus acus*), Cynoglossiidae (*Cynoglosus senegalensis*), Paralichthyidae (*Syacium guineensis),* Dasyatidae *(Dasyatis margarita),* Elopidae *(Elops lacerta),* Synodontidae *(Saurida caribbaea*), Clupeidae (*Sardinella maderensis*), Pristigasteridae (*Ilisha africana*), lophidae *(Lophius vaitlanti),* Drepaneidae *(Drepane longimana),* Monodactylidae *(Monodactylus sebae),* Sphyraenidae *(Sphyraena guachandro*), all had a single species from one genera. A combination of fishes reported by these in this area is shown in Table: 4.10.1.

Table 4.10.1: Study Area Common Fish Species of Commercial Importance

S/N	Family	Scientific name	Common name
1	Lutjanidae	*Lutjanus agennes* *Lutjanus gorensis*	African red snapper Gorean snapper
2	Rajidae	*Raja miraletus*	Skates
3	Dasyatidae	*Dasyatis pastinaca*	Stingray
4	Pristigasteridae	*Ilisha africana*	West African Ilisha
5	Lophidae	*Lophius vaitlanti*	Shortspine African angler
6	Sciaenidae	*Pseudotolithus (F.) elongatus* *Pseudotolithus (Pinnacorvina) epipercus* *Pseudolithus senegalensis* *Pseudolithus (P.) typus* *Pteroscion peli*	Bobo croaker Guinea croaker Cassava croaker Longneck croaker Boe drum
7	Elopidae	*Elops lacerta*	Ten pounder
8	Belonidae	*Tylosurus acus acus*	Needle fish
9	Cichlidae	*Sarotherodon melanotheron* *Oreochromis mossambicus* *Coptodon zillii*	Tilapia
10	Monodactylidae	*Monodactylus sebae*	Moon fish
11	Drepaneidae	*Drepane longimana*	Concertina fish
12	Scombridae	*Scomberomorous tritor*	Scomberomorous
13	Mugilidae	*Liza falcipinnis* *Mugil cephalus*	Sickle-fin mullet Flathead grey mullet
14	Ariidae	*Arius heudeloti* *Arius latiscutatus*	Sea catfish
15	Bagridae.	*Chrysichthys nigrodigitatus*	Bagrid catfish.
16	Pomadasyidae	*Brachydeuterus auritus* *Parapristipoma octolineatum* *Pomadasys jubelini*	Bigeye grunt African striped grunt Sompat grunt

S/N	Family	Scientific name	Common name
17	Polynemidae	*Galoides decadactylus* *Pentanemus quinquarius* *Polydactylus quadrifilis*	Smaller African threadfin Royal threadfin Giant African threadfin
18	Carangidae	*Caranx spp.* *Trachurus trachurus* *Chloroscombrus chrysurus*	Jacks Atlantic horse mackerel Atlantic bumper
19	Clupeidae	*Ethmalosa fimbriata* *Sardinella maderensis*	Bonga shad Madeiran sardine
20	Cynoglossidae	*Cynoglossus browni* *Cynoglossus canarensis* *Cynoglossus monodi* *Cynoglossus senegalensis*	Nigerian tonguesole Canary tongue Guinea tonguesole Senegalese tonguesole
21	Serranidae	*Epinephelus aeneus* *Epinephelus alexandrinus* *Epinephelus caninus* *Epinephelus guaza (= E. gigas)*	White grouper Golden grouper Dogtooth grouper Dusky grouper
22	Sparidae	*Boops boops* *Dentex angolensis* *Pagellus bellottii (= P. coupei) Sparus pagrus pagrus*	Bogue seabream Angola seabream Red pandora Common seabream

(Source: Troadec and Garcia, 1980; Ibim and Bongilli, 2018)

Fish Species Landed and Fishermen Involvement

The species composition of the fishermen catches in the area is shown in Table 4.10.2. The analysis of catches in this study reveals that *Caranx spp* constituted the most dominant fish species landed by the fishermen (Plates 4.10.2, 4.10.3 & 4.10.4). This was followed by *Dentex angolensis and Epinephelus aeneus* of the fishermen catches. *Sepia officinalis* was among the least common fish species hauled by the fishermen. Comparing the number of fishermen hauling particular fish species and the amount of fish landed, the *Caranx spp* was found to be the most hauled fish species by the majority of fishermen.

In addition, the commercial abundance of the species may also have impacted on its value making it an affordable source of protein. This may be associated with the upwelling seasons which result in food abundance for the species (*Caranx spp)* resulting in its abundance. Some fish species such as *Thunnus sp* and *D. margarita* were hauled in low quantities by few fishermen giving the indication of either dwindled stocks or these species are not actively targeted by the fishermen. However, *Dentex* spp. are targeted by relatively high number of fishermen even though the percentage catches are not very high.

Table 4.10.2: Fish species composition of fishermen catches in the area

S/N	Family/ Species	Common Name	Local conservation status
1	**Balistidae** *Balistes puntactus*	Bluespotted triggerfish	C
2	**Carangidae** *Caranx hippos*	Crevalle jack	A
3	*Caranx crysos*	Blue runner	R
4	*Alectis alexandrines*	African threadfish	C
5	*Chloroscombrus chrysurus*	Atlantic bumper	A
6	**Clupeidae** *Sardinella aurita*	Round sardinella	A
7	**Pomadasysidae** *Pomadasys jubelini*	Sompat grunt	C
8	**Sparidae** *Dentex canariensis*	Canary dentex	A
9	*Dentex sp*		A
10	**Sphyreanidae** *Sphyreana barracuda*	Barracuda	C
11	**Drepanidae** *Drepane Africana*	African sickle fish	C
12	**Cynoglossidae** *Cynoglossus senegalensis*	Sole	R
13	**Elopiidae** *Elops lacerta*	West African ladyfish	C
14	**Ephippididae** *Chaetodipterus goorensis*	African spadefish	C
15	**Scieanidae** *Pseudotolithus elongatus*	Bobo croaker	C
16	*Pseudotolithus senegalensis*	Cassava croaker	C
17	*Umbrina canariensis*	Canary drum	C
18	**Scombridae** *Scomberomorus tritor*	West African Spanish mackerel	C
19	*Thunnus sp*	Tuna	R
20	**Serranidae** *Epinephelus aeneus*	White grouper	C
21	**Sepiidae** *Sepia officinalis*	Common cuttlefish	R
22	**Portunidae** *Portunus Validus*	Smooth crab	C

NB: A =abundance, C = common, R =Rare

Plate 4.10.2: Species composition of catches from small-scale fishery in the project area

Plate 4.10.3: ***Sphyreana barracuda*** **(a),** ***Caranx*** **sp (b)and** ***Chaetodipterus goreensis*** **(c) caught around the project area**

Plate 4.10.4: Some of the fishes caught by the small-scale fishermen around the project area

Apart from the small-scale fisheries solely depend upon by the local for food and profit, industrial fishing also occurs in the project area. The trawlers operate day and night but recently they have to operate with caution due to pirate attacks. The Fishing Trawlers Owners Association of Nigeria listed some of the challenges facing the industry to include inconsistent government policies, and the porosity of Nigerian waterways. The biggest challenge facing the fish trawling industry in Nigeria is pirate activities and armed robbery at sea. Piracy has become a menace on Nigerian waterways posing a major challenge for every maritime related business in the country. It is sad that whilst maritime business in the country is experiencing a decline, piracy and armed robbery are gaining more grounds. What is now obvious is the inability of the current security strategy to protect Nigerian investors that conduct business on the sea. This calls for an urgent review of our waterways security strategy in the interest of the nation. The local benefit from this sector by buying mixed fishes and bycatch from the for sale and their local markets.

The industrial fishery also causes problems to the small-scale fisheries by destroying their nets, this has caused some conflict among them (Small scale and industrial). Legally, the “Sea Fisheries (Fishing) Regulations and the “Sea Fisheries (Licensing) Regulations” are the two laws that seek to regulate the fishing and trawling business in Nigeria. The Sea Fisheries (Licensing) Regulations forbids any unlicensed vessel from trawling on Nigerian waters. However, contrary to the dictates of this law, observers have suggested that some strange, foreign, and unlicensed ships come into the country’s waters to trawl without any form of questioning from relevant authorities, which presupposes a connivance of some sort at the expense of local operators. The current situation demands intervention of the government. The private sector in any industry cannot deliver to its fullest without an enabling environment, which is the responsibility of the government.

Plate 4.10.5: Fishing trawler operating around the project area

Fish preservation in marine fisheries

The small-scale fishery in the area has adopted a technique to preserve their fishes from deteriorating for two to three days by using improvised cold room constructed from plywood and stainless steel filled with iceblocks (Plate 4.6). This has prolonged the shelf life of their catches for two to three days.

Plate 4.10.6: Fishes preserved in an improvised cold room by fishers around the project area

The fishes in the area were said to have increased over the years compared to like 20 years ago in terms of number. This may be as a result of the length of nets used now and the distance the fishermen covered. Despite this, some species of fish have been identified as scare or not available. These are *Lutjanus goorensis*, guitar ray, ray fish, giant *Tarpon atlanticus*, sea tortoise, *Pristis sp* (sawfish) and *Torpedo torpedo*. The scarcity of these species may be as a result of the pressure on the fishes and increased number of fishermen.

Fish Migration

Migratory fish require different environments for the main phases of their life cycle which are reproduction, production of juveniles, growth and sexual maturation. The life cycle of diadromous species takes place partly in fresh water and partly in sea water: the reproduction of anadromous species takes place in freshwater, whereas catadromous species migrate to the sea for breeding purposes and back to freshwater for trophic purposes. The migration of potamodromous species, whose entire life cycle is completed within the inland waters of a river system. Fish migration is a phenomenon associated with reproduction, or food availability. Some of the exploited fish species, e.g., bonga, croakers, sardinella, snappers, threadfins, pink shrimp and barracuda, make seasonal migrations from the sea into the creeks and back to sea, mainly for reproduction. Such migrations are likely to influence movement of fishing units along the coast. The migration of these species can influence migration of fisher folks in the they may be more concentrated in a at a particular time of the year than the other area which will affect the catches. Besides, the onshore/offshore and lateral migrations mean that several stocks are harvested by both artisanal and industrial fleets. However, by the nature of the project, fish migration is not affected by the project because the diversity recorded has not been seriously affected. Although, fisher folks in the area noted that fishes in the area have drastically reduced due to interest and pollution that has rampage the area in recent times. In addition to these people also assumed that they are not secured fishing in the area due to security tension in the area this has limited fishing activities to the open waters where they can still be sure of safe operation.

Fish Breeding

Fish breeding in the entire area is very likely as varying sizes of fishes are caught by fishers in this area and the shore line is not in any way tampered or affected by the project. Adult fish that are ready for breeding are known to swim to shore areas or shallow parts of the river where they can lay their eggs and care for their young. These areas are also expected to be rich with enough micro food organisms for their young and fewer predators as well as disturbance. Such areas are mainly creeks and rivulets.

4.11: Biodiversity Studies

4.11.1: Methodology

Information on the biodiversity of the Project area was obtained from desktop and field studies. A number of relevant literature on the aquatic environments in Niger Delta (Eziuzo, 1965; Awosika, 2001; Omoweh, 2005; Agbeja, 2010; Fishbase, 2010; Ayanwale, *et al*., 2013; Elenwo and Akankali, 2015) were consulted. The reports indicated the presence of seven mammalian species, thirteen avian species and three reptilian species. IUCN (2018) also listed the protected Endangered *Chelonia mydas* and the Vulnerable *Lepidochelys olivacea* as members of the aquatic communities within the project area. Field sampling for biodiversity studies was conducted from January 16^{th} to 21^{st}, 2019. The study team included a systematist, a mammalogist, an ornitlogist and a herpatofauna expert. The team also included three local assistants. A 10 km^2 spatial boundary was established for the study.

Reptiles and Mammals

Two types of surveys were employed for mammalian studies. In one instance, surveys were conducted along a 5.5 km stretch of near shore water, extending 1 km into the sea to depths of up to 5 m. The surveys were conducted over a total of 47 hours over a 3 days period. The surveys were carried out from 10:00 to 18:30, and 06:00 – 08:00. A hydroscope was deployed for underwater observations while the underwater camera was used for image capturing. On sighting a sea turtle, with the aid of the hydroscope, trained personnel will enter the water and quietly approach the target animal (s) until within underwater visual range (subject to daily variations in underwater visibility) for image capturing and behavioural studies. The locations of sightings were recorded using GARMIN Etrex-legend GPS. Other data collected at the location of sightings included biological, environmental, depth, tidal regime, sex of species, sexual dimorphic features and behavioural traits such as response to presence of underwater observers.

In the second instance, boat surveys covering up to 10 km base radius from Kongho community shoreline were conducted. Line transects across the entire survey area were established during each survey session. Marine wildlife sightings were achieved using hydroscope. At sighting locations, the GPS location, depth, time, gender (if possible), the tidal regime and behavioural responses were recorded. The hydroscope has a maximum range of 40 m so wildlife living beyond 40 m depth was not captured. Water samples were collected at every depth where aquatic mammals were sighted for in situ and laboratory studies.

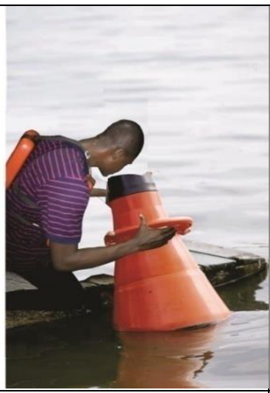
		
Biodiversity Study Team	Hydroscope study	Underwater Camera

Plate 4.11.1: Biodiversity studies Crew, Hydroscope and underwater camera used for marine biodiversity studies

Avian Survey

The bird surveys provided information on:

- Number/density of birds regularly present or resident within the study area
- Patterns of bird movements in the study area
- Presence, abundance and use of habitats from endemic and threatened species in the study area
- Breeding/wintering grounds if present

Migration Survey

The observation stations were located in the open sea where the Reptilian and Mammalian studies were conducted. At each station, observations were made for about 60 minutes with the aid of binoculars. Avian surveys were carried between 8:00 and 16:00 hours to maximize the observations, as migrating raptors travel more frequently at this time of the day. Birds observed and their travel characteristics were obtained. Records included the sequential number of the observation, the number of individuals, the activity (e.g. flight, feeding, resting), the flight direction and the approximate distance from the ground. When possible, the ages of the birds (adult or juvenile) were also determined. Pictures were taken on the inventoried habitat.

Conservation Status

The global conservation status of all species was obtained from the IUCN Red List of Threatened Species Version 2018-2 while Endangered Species Act 2016 was used in compiling the national status.

Turtle Nesting Sites

All species of sea turtles exhibit an oviparous reproductive strategy that requires gravid females to return to their natal beaches to lay eggs. While eggs remain buried in the ground during the 45–65 days incubation period, they are exposed to an array of environmental variables that influence the development of eggs and hatchlings (Standora and Spotila, 1985, Booth, 2006, Burgess *et al*., 2006). Several observed and potential nesting sites were reported in the draft ToR for the studies. These sites and others were further highlighted during the scoping workshop as well as information from relevant literature and information from the Akassa Development Foundation (ADF).

A total of four established and two potential nesting sites were studied. Soil samples were collected at the nesting sites. Selection of nesting sites for studies was based on some characteristic features which included

- Areas relatively devoid of debris
- Reduced anthropogenic activities such as fishing, movements and motor cycling riding as well as
- Newly exposed soil surface.

The pictorial imagery of the nesting sites is provided in Plate 4.11.2. Soil Auger was used to collect representative soil sample at each station at depths of 0-60 cm. Soil samples for physical and nutrient analyses were sub-sampled and appropriately labelled to indicate sample location and soil depth level. Soil samples for hydrocarbon contents analyses were collected into amber glass bottles and labelled appropriately.

Table 4.11.1: Turtle nesting sites and Soil sampling locations

Name of Community	Coordinates	Elevation (Ft)	Length (m) of shoreline to nesting site
Monokiri	4.3251/6.5509	8	29.3
Macleankiri	4.3326/6.5822	11	19.6
Opupopokiri	4.3288/6.5379	6	19.1
Idegeba	4.3256/6.5782	5	19.4
Kula kiri	4.3238/6.5379	9	15.1
Odiama	4.3267/6.5361	4	11.5

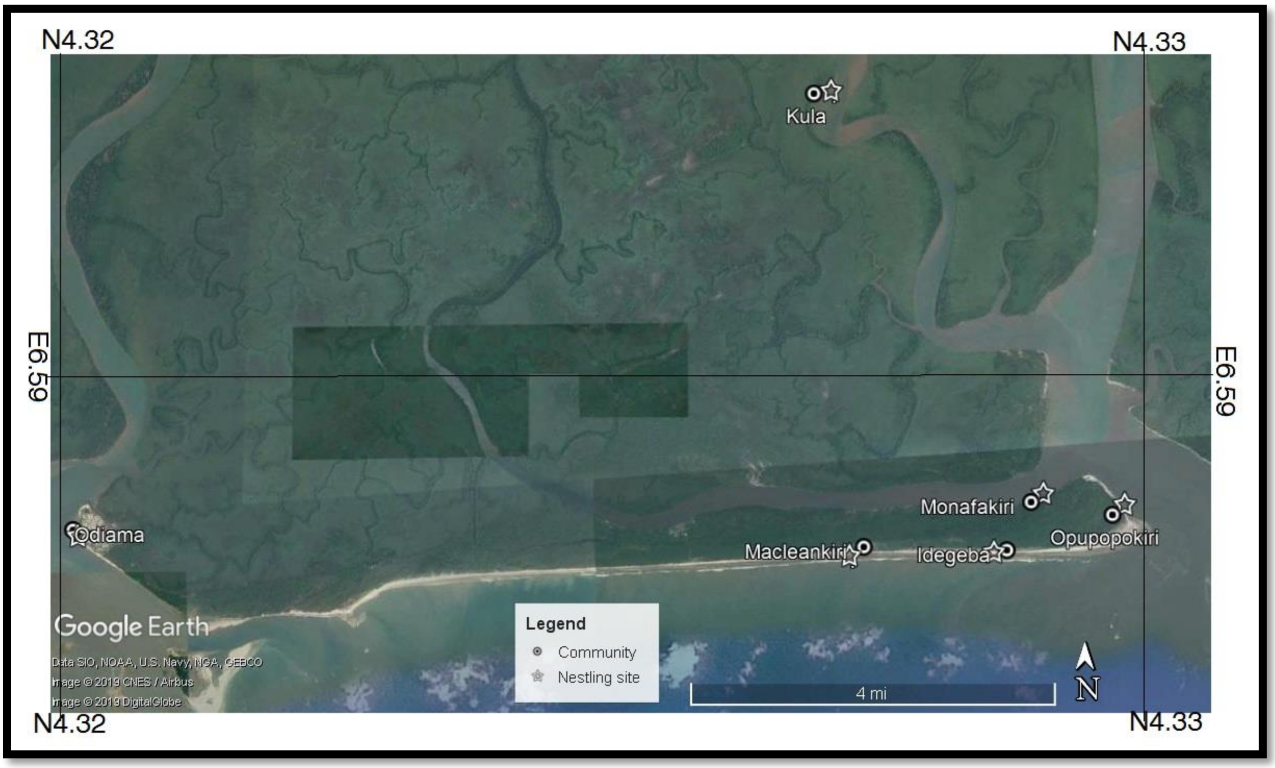


Fig. 4.11.1: Aerial imagery of Turtle nesting sites where soil samples were obtained

Plate 4.11.2: is the pictorial imagery of the delineated nesting sites

4.11.2: Reptilian Studies

Species Diversity

Two mammalian, two reptilian and 18 avifauna species were sighted during the study while three mammalian and three reptilian taxa were censored via indirect evidences. The species sighted were *Chelonia mydas* (Green turtle) and *Lepidochelys olivacea* (Olive Ridley) (Plate 4.11.3) both in the order Testudines.

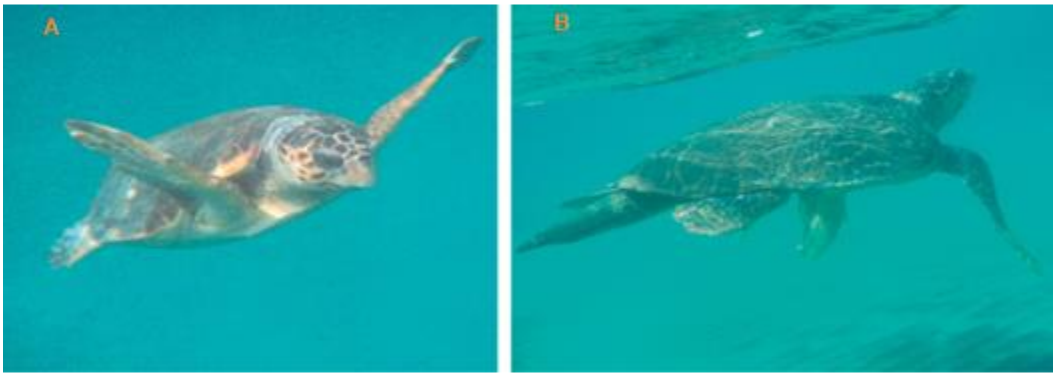


Plate 4.11.3a: *L. olivacea* photographed under water during the study

Plate 4.11.3b: Dermochelys coriacea (Leatherback Sea Turtle) sighted along the beach

The occurrence of these species has been reported previously (Abayomi, 2017, Oyeronke, 2013, Akani and Luiselli 2009, AGIP 2014). The Leatherback sea turtle (*Dermochelys coriacea*) and Loggerhead sea turtle (*Caretta caretta*) in the order Testudines as well as *Crocodylus niloticus* (Nile crocodile) in the Order Croccodylia were censored via various indirect evidences. Table 4.11.3 shows the location of the sighted reptilian species. Individuals of the two sighted species were sighted in six locations (Table 4.11.2, Figure 4.11.2).

Table 4.11.2: Locations of sightings of sea turtle species during the study

Locations	Coordinates	*Chelonia mydas*	*Lepidochelys olivacea*
A	4.322492/6.517172	+	+
B	4.324894/6.678200	+	+
C	4.3274930/6.564475	+	
D	4.329186/6.429375	+	

While *Chelonia mydas* was sighted in four locations, *Lepidochelys olivace* was sighted in only two of the locations. The sites for *Chelonia mydas* are located about 139 m, 217 m, 385 m and 239 m from Negetekiri, Idegeba, Ibidi and Odama communities respectively while the sites for *Lepidochelys olivacea* were about 254 m and 348 m from Macleankiri and Monafakiri.

Fig. 4.11.2: Locations of sea turtle sightings during the study

Species Abundance

A total of 15 individuals of turtle species were sighted, 9 of which belonged to *Chelonia mydas* and 6 to *Lepidochelys olivacea*. Carcasses of two individuals of *Chelonia mydas* consumed by the people were also observed and documented during field activities. Three of the Seven (7) sighted individuals were in Location C, two (2) individuals in location D while one (1) each were censored in Location A and B (Table 4.11.3). On the other hand, four (4) individuals of *Lepidochelys olivacea* were in location A while 2 were censored in location B.

Sex

A clear gender distinction was observed in the two species. Four sexual dimorphic characters were used either in isolation or in combination for gender identification among the adult populations. They are lengths of carapace, claw, tail and position of cloacal opening. Sexual dimorphism is non-existent among juveniles. However, the occurrence of black- greenish back among the species was used as juvenile identification in *Chelonia mydas*. The gender of two individuals of *Chelonia mydas* could not be determined at sight while 6 were identified to be females and 1 a male. The gender of the five individuals of *Chelonia mydas* caught showed that four were adult females and one was male. On the other hand, 5 females and one male individuals of *Lepidochelys olivacea* were identified. It was observed that the four caught females of *Chelonia mydas* were found on the shorelines as against the only male that was found along the shallow waters. All individuals of *Lepidochelys olivacea* were all censored along shallow waters.

Time/Tidal regime at sightings

Four (4) individuals of *Chelonia mydas* were sighted at dawn during ebbing hours while 3 were sighted at late night during flooding regime. These findings implied that the species often migrate to shallow surface waters when anthropogenic influences are at minimal (most likely during night time) and return back to higher depths/offshore areas during day with higher episodes of anthropogenic disturbances. On the other hand, the four female individuals of *Lepidochelys olivacea* were sighted at twilight during flooding hours while the other two were sighted very early morning during flooding hours.

Depth of sightings

The sighted individuals of *Chelonia mydas* were observed in the neritic zone of the water bodies, at approximate depth of about 5.4 m while those of *Lepidochelys olivacea* were observed at an approximate depth of 3 m to 9 m. They were also observed not more than 400 m away from the shorelines. Similar depth range for the species was reported by Reisser, *et al*. (2013). Such shallow depths make them susceptible to human threats and injuries.

Movement

It was observed that all Rideley individuals sighted swim vertically up (to lower depths) during flood tide regimes and swims parallel to the shorelines during ebb tide regimes. This contrasted with the swimming pattern of *Chelonia* which was vertically upward during flooding and diagonally during ebbing sequences.

Behavioural Activity

Behavioural activities during sighting events were grouped into two, Solitary and social. The solitary events evaluated for included swimming (this includes in the water column and near the sea surface as well as patrolling by males), foraging (mining for bivalves) and cleaning (this includes both self-cleaning and symbionts cleaning). When self-cleaning, they repetitively rubbed their heads and flippers and carapace against submerged rocks or anchors) and surface basking (Surface- basking were observed up to 1 m beneath the sea surface with the head and flippers lowered) as a resting behaviour. Antagonistic interactions (this included female–female and male–male interactions) and reproductive activities (this includes courtship and copulation with and without male attendants) were the two social behaviours evaluated. The result over five sighting events revealed female-female contest for those sighted off Macleankiri. Nine were engaged in swimming and one cleaning. Expression of these behavioral activities is indicative of conducive habitat. Although swimming could be suggestive of predator avoidance or presence of unfavorable physico-chemical conditions.

Food Habits

Turtles begin their lives as omnivores and food comprises flesh and vegetal diets (Arthur, *et al*., 2008; Russell, *et al*., 2011). Juveniles of *Chelonia mydas* were reviewed as having different diet type from adult populations. Their food includes small marine invertebrates and sea serpents moss, Bryozoa, and sea hare eggs (Arthur, *et al*., 2008; Russell, *et al*., 2011; Seminoff, 2004; Spotila, 2004). Wetland plants found on salt marshes have been documented as part of their food regimes. Other include several alga species, Caloglossa (red moss), lobster horns, sea lettuce, green seaweed, and crinkle grass. Because they are highly mobile throughout their lives, their food choices are often opportunistic (Seminoff, 2004; Spotila, 2004). These food sources have been reported in this water bodies and adjoining ones (Forbes, 1996; Higgins, 2002; Seminoff, 2004; Spotila, 2004; Kadiri, 2006; Tiseer, *et al.*, 2008, Arthur, *et al*., 2008; Russell, *et al*., 2011).

Indigenous Uses of Species

In the project area, the species is poached for eggs and as meat. Locals claim the species form a palatable combination with beans soap. The two reptile species are used in tradition medicine and their shells are used to adorn some traditional masquerades. All turtle species are locally called Obo by the locals.

Predation

The hatchings of *Chelonia mydas* and *Lepidochelys olivacea* are at a higher risk of predation than adult green sea turtles. Eggs are preyed upon by multiple land mammals, reptiles, and crustaceans (Kennedy, 2019). Young green sea turtles also are consumed by crabs (Brachyura) which can attack them both on land and in the water. The huge nesting sites around the ox bow lake typed water bodies is perhaps an adaptive protective mechanism. However, the hatchlings face other predatory threats in the water. Large mammals, reptiles and humans are the main threat in the water bodies. Attacks from trawlers and oil exploration vessels have also been documented (Kennedy**,** 2017**;** Gardner, 1998). Green turtles are also hunted by humans for meat.

Conservation Status

Chelonia mydas is categorized as Endangered (EN) species according to the IUCN Red List while *Lepidochelys olivacea* is categorized as Vulnerable (VU). The Convention on International Trade in Endangered Species classifies green *Chelonia mydas* under I which include species that are most endangered and most at risk of extinction. This specific explains that trade of this species is prohibited unless the species is being used for research. Exceptions to this prohibition are only valid under approval of import and export permits. In Nigeria, these species are categorized as Endangered. In Akassa, the ADF actions have helped in their conservation, although absence of trained personnel, funding and referral centers to treat injured populations are impediments.

Ecosystem Roles

Juvenile *Chelonia mydas* and *Lepidochelys olivacea* are predators of sea serpents (Hydrozoa), moss animals (Bryozoa), sea hare eggs (Aplysia) and small jellyfish (Medusoza) while adults are mostly herbivorous and consume large quantities of sea grass and algae. Both species play a role in their ecosystem by facilitating nutrient turnover and sea grass regrowth (Aguirre, *et* *al*., 1998). As they graze on sea grass, they provide nitrogen-rich fertilizer in the form of fecal matter. Green sea turtles suffer from parasitic trematode eggs known as flukes (Aragones, *et al*., 2006). These trematodes cause inflamed cardiovascular tissue that infect turtles and commonly result in death (Raidal, *et al*., 1998). Species of flukes that are found in green turtles include: *Learedius leardei, Carettacola hawaiiensis, Hapalotrema dorsopora*, and *Hapalotrema postorchis* (Raidal, *et al*., 1998).

Proposed Management Plan

Delineation and access restriction to identified nesting sites, construction of egg chambers and capacity training for ADF members. The establishment of medicare centres would aid treatment of injured individuals before re-introduction to the wild. It should be a component part of the enlarged Aquatic Species Management Plan proposed to be developed prior to seismic operation.

Soil Quality at Turtle Nesting Sites

Results of the measurements are presented in Table 4.11.3. Soil profiling conducted on the identified nesting sites revealed same elevation with the water bodies or one with slowly increasing elevations. All identified sites were observed to be less than 11ft above mean sea level. The relative distance of the shoreline to the farthest identified nesting site is in Monakiri sea side which was about 29.3 m. This area was the only site below mean see level characterized with the absence of debris and stronger turbulence. The nesting sites were characterized by pools of water interspaced with soil.

Table 4.11.3: Physicochemical Results of soils at nesting sites

Parameters	Mean of Established Nesting Site	Mean of Potential Nesting Sites	Statistical Difference (P-value at P<0.05)	Reviewed Range for Turtle nests
pH (H_2O) @ 24.8^oC	4.73±0.31	4.71±0.04	0.934	5-8
Temperature (^0C)	31.7	30.6	0.15	30-32
Elect. Cond. (mS/cm)	1.79±0.07	1.27±0.05	0.001*	0.3-1.0
Organic Carbon (g/kg)	3.74±0.30	3.42±0.15	0.066	
Moisture Content (%)	15.7	15.4	0.86	15-18
Sand	89.27±5.10	90.13±4.00	0.834	$\geq$85%
Silt	6.91±0.26	5.74±0.05	0.015*	$\leq$10%
Clay	3.82±0.05	4.14±0.13	0.037	$\leq$5
TPH (C_8-C_{40}) (mg/kg)	<0.05	<0.05	-	
THC (mg/kg)	<10.00	<10.00	-	
Total Nitrogen (mg/kg)	2.08±0.18	0.56±0.02	0.004*	
Chloride (mg/kg)	18.87±0.03	15.62±1.55	0.070	3.75-5.46
Extractable Nitrate (mg/kg)	0.43±0.08	0.31±0.07	0.112	

Parameters	**Mean of Established Nesting Site**	**Mean of Potential Nesting Sites**	**Statistical Difference (P-value at P<0.05)**	**Reviewed Range for Turtle nests**
Ext. Sulphate (mg/kg)	1.75±0.04	0.05±0.02	0.000*	
Ext. Phosphate (mg/kg)	13.32±0.61	13.30±0.48	0.970	
Magnesium (mg/kg)	975.00±15.17	502.00±64.15	0.008*	205-363
Potassium (mg/kg)	10,562.00±71.36	9,404.00±451.44	0.048*	
Sodium (mg/kg)	5,738.00±228.48	4,294.00±356.40	0.006*	55-145
Calcium (mg/kg)	3,541.00±93.25	2,690.00±105.67	0.001*	148-353
Total Chromium (mg/kg)	2732.95±434.76	<0.10	-	
Total Iron (mg/kg)	15,550.00±613.83	10,487.00±603.70	0.000*	
Copper (mg/kg)	52.10±5.02	<0.50	-	0.19-0.52
Lead (mg/kg)	4.71±0.17	3.13±0.13	0.001*	1.05-2.34
Nickel (mg/kg)	21.40±1.52	20.19±1.83	0.491	
Arsenic (mg/kg)	7.31±0.24	<0.50	-	
Selenium (mg/kg)	<0.10	<0.10	-	
Molybdenum (mg/kg)	1.28±0.03	0.10±0.00	0.000*	
Zinc (mg/kg)	15.11±0.51	6.15±1.04	0.001*	0.38-0.84
Cadmium (mg/kg)	<0.10	<0.10	-	0.25-0.52
Mercury (mg/kg)	<0.10	<0.10	-	
Barium (mg/kg)	<2.00	<2.00	-	
Aluminum (mg/kg)	37,129±2318	31,210±1312	0.093	
Vanadium (mg/kg)	13.32±0.10	2.09±0.06	0.000	
Manganese (mg/kg)	232.13±13.65	267.35±31.03	0.811	

The particle size distribution for the soils from the nesting sites showed a sandy texture (89% to 90% sand). The pH levels of all the nesting soils were acidic. This may not be unconnected with the general leaching effect in Niger Delta (Abii and Nwosu, 2009) that renders most soils acidic. No significant difference was observed for pH values obtained between the established nesting sites and potential nesting sites. The pH values obtained for both nesting grounds conformed with those reported by others (Sükran Yalçın-Özdilek, 2005, Bouchard, 2000, Canbolat, 2004).

The temperature values obtained from the established (31.7^{o}C) and potential (30.6^{o}C) nesting sites compared well with results obtained in similar studies (Drake 2002, Sükran Yalçın-Özdilek, 2005, Girondot, 2015, Zoey, 2017). No significant difference was observed for mean temperature values obtained in the established nesting grounds and potential nesting sites. The principal temperature that produces both sexes is called the transitional range (TR) and typically only spans 1–4°C (Wibbels, 2003). In *Dermochelys coriacea*, the TR is 1°C or less (Binckley *et al.*, 1998, Chevalier *et al.*, 1999). Temperature during incubation also influences hatching success (Harley *et al*., 2006). In *Lepidochelys olivacea*, incubation temperature greater than 35°C result in the death of developing embryos and failure to produce any hatchlings (Valverde *et al*., 2010).

The moisture content obtained from the established (15.7%) and potential (15.4%) nesting sites compared well with results obtained from similar studies (Mcgehee 1990, Ralph *et al*., 2005, and Matsuzawa *et al*., 2002). No significant difference was observed for mean moisture content values obtained in the established nesting grounds and potential nesting sites. Moisture content also interacts with temperature to influence hatchling morphology in turtles including the hatching sizes (McGehee, 1990) and may also influence the hatchling sex (Carthy *et al*., 2003, Wibbels, 2003). Godfrey *et al*. (1996) found increased production of male hatchlings in green turtle (*Chelonia mydas*) and leatherback turtle (*Dermochelys coriacea*) nests during April and May, months with the most rainfall in Suriname. High moisture content decreases gas diffusion throughout the nest (Miller *et al*., 2003), which can cause egg death if extreme. Result obtained for moisture content compared favourably with those reported by others (Brook, 1989, Crain *et al*., 1995, Foote and Sprinkel, 1995). Over 90% of the soils in the nesting sites contain sand particles with grain sizes of above 2 mm. Reports show that green turtles tend to abort nesting at sites with sands of particle sizes < 1mm while large particulate sizes may be preferable in terms of gas exchange between nests and surrounding sand (Mazaris *et al*., 2008). However, Mortimer (1990) linked the inhibition of green turtle digging and reduction in hatching success to large sand particle sizes. The negative effects of large sand particle size may be caused by high compactness of sand (Chen *et al*., 2017).

Significant difference ($P<0.05$) was observed between established and potential nesting sites for Electrical conductivity, total Nitrogen content, Exchangeable sulphate, Magnesium, Potassium, Sodium, calcium, Iron, lead, Molybdenum, and Zinc. This amounts to about 30% of the total analyzed parameters. These differences could be due to the variation in topography and parent material of the soil.

4.11.3: Avifauna Studies

Species richness

A total of eight (18) sighted avian species were censored (Table 4.11.4). Some of the sighted species include *Nycticorax nycticorax, Casmerodius albus* and *Phalaropus fulicarius* (Plate 4.11.3).



Nycticorax nycticorax	*Casmerodius albus*	*Phalaropus fulicarius*

Plate 4.11.3: Representative avian taxa censored

Table 4.11.4: Check list of Censored Avian species and their specific traits

S/N	Species	Frequency	Abundance	Behaviour	Sex	Flight Direction	Altitude
1	*Botaurus stellaris*	1	1	F		NE	0-50
2	*Ardea cinerea*	1	1	F		NE	50-75
3	*Ardea goliath*	1	4	R.F,F,FL. F,F	F,F	NE,NW. NE	0-5-,50-75,50-75. 50-75,50-75
4	*Ardea cinerea*	2	2	F.F,F	M	NE. SW	0-50. 50-75,50-75
5	*Actophilornis africanus*	1	1	FL		SW	75 & ABOVE
6	*Microparra capensis*	1	6	F,R. F.F	F,M,M	NE. NE. NE	0-50,0-50. 50-75. O-50
7	*Anastomus lamelligerus*	2	1	F. FL. F,F		NE. SW	0-50. 50-75. 0-5-,0-5-
8	*Casmerodius albus*	2	6	R. F		NE. SW	0-50. 0-50
9	*Anas crecca*	1	4	FL. FL. R		NE. SW	50-75. 50-75
10	*Nycticorax nycticorax*	3	2	F. R. R		NE, NE	0-50. 50-75, 50-75
11	*Bubulcus ibis*	2	3	FL. R		SW. NE	50-75. 0-50
12	*Calidris alba*	1	2	R,R		SW	50-75,50-75
13	*Sterna caspia*	2	7	R,FL. RF. FL,R	M	NE.NE NE,NE	0-50,50-75,50-75. 0-50. 50-75,0-50
14	*Ardenna grisea*	1	3	F,F,FL. F,F,F		NE. SW	0-50,50-75. 0-50. 0-50,0-50
15	*Hydrobates leucorhous*	1	6	R,R	M	NE,SW. SW,NE	50-75,50-75
16	*Phalaropus fulicarius*	2	4	R. R,R,FL		NE. NE	0-50,50-75. 50-75,50-75
17	*Stercorarius longicaudus*	1	4	FL. FL. FL	F	NE. NE	50-75. 50-75,50-75
18	*Stercorarius pomarinus*	1	4	F. F		NE	50-75
Key: F = Feeding; FF = Flight; R = Resting							

Species abundance

A total of 61 individuals were censored across the counting and observation stations. Results showed that *Nycticorax nycticorax, Casmerodius albus, and Phalaropus fulicarius* accounted for about 40% the total counts.

Species Frequency

Bird frequency studies showed that *Nycticorax nycticorax, Casmerodius albus, Ardea cinerea, Anastomus lamelligerus, Bubulcus ibis, Hydroprogne caspia , Phalaropus fulicarius* were the most frequent. These species were observed in at least two different habitats making them highly adaptable to wider food source as food availability in habitat varies. Those observed in only one habitat are highly specific and enjoy territorial dominance. However, they encounter declining population and range when their habitat is challenged with threats.

Bird Behaviour

Three behavioural tendencies were evaluated at the time of censoring. They were feeding, resting and flight. A total of 14 individuals were observed in flight while 20 were observed resting. Twenty-seven (27) individuals were observed feeding. In terms of habits, Nine individuals each were observed during feeding and on flight as against 11 resting. *Botaurus stellaris ,Ardea cinerea and Stercorarius pomarinus* were always observed feeding, *Porphyrio porphyria, Calidris alba and Hydrobates leucorhous* were observed always resting. *Actophilornis africanus* on the other hand was always on flight. Others did not portray any definite patterns.

Flight direction

Flight direction was equally observed and evaluated. The birds were observed flying in three main directions. Ten individuals were observed flying in the NE direction as against one flying in the North westerly direction. Seven individuals were observed flying in the south westerly direction for which all *Actophilornis africanus* were remarkably seen flying in the south westerly direction only. Nevertheless, there was no observable peculiarity in flight direction among other bird species.

Sex evaluation

The bright colouration of the male was used as discriminatory character. A total of 10 individuals were identified as belonging to any of male or female. Six were female and four were male. No defined flocking pattern was observed either among the individuals or among the specific sexes in any of the habitats.

Altitude

Results of Flight altitude studies showed that one individual was flying within 0-50 m altitude. Thirteen (13) individuals were observed within the 50-75 m range while 3 were seen flying above 75 m. Other species were observed in the 50-75 and above the 75 m active while in flight. There was only one species observed exclusively within the 0-50 m range. Species within this altitudinal range seems attracted to feeding and resting. A strong correlation coefficient of 0.74 was obtained between altitude and bird behaviour in this study.

Species migration

Some avian species are known to migrate (Plate 4.11.4). Avian migration is either regular or irregular (Nomadic interruption or invasions) seasonal movement between north and south. Avian migration is usually driven by food, habitat and changes in weather conditions. These movements are usually between breeding and wintering grounds (veen *et al.*, 2014). In Nigeria as in other countries in the Northern hemisphere, migratory birds commence this movement between February, March and April to warmer areas and return between August, September and October to winter grounds. Migratory movement often results in high mortality and predation.

		
Ardea cinerea	*Anas crecca*	*Ardenna grisea*

Plate 4.11.4: Migratory Species of the study area

Raptors

A diurnal predatory bird that hunts and feed on rodents, insects and small animals exerts strong biodiversity influences on the ecosystem. In such environments, they act as key stone species by regulating their prey population. Some are known as 'Earth Cleaners; for their role in eating up dead carcasses. Raptors are members of Accipitridae, Pandionidae, Sagittaridae, Falconidae and Cathartidae of Acciptriformes, Apodidae and Falconiformes orders (Fowler *et al*., 2009). In this study, a total of 9 raptor species, belonging to Ardeidae , Podicipedidae , Scolopacidae and Ciconiidae families were sighted. Table 4.11.5 shows details of raptors sampled in the study area.

Table 4.11.5: Raptors of the Study Area

S/N	Species	Common Name	Prey
1	*Ardea cinerea*	**Grey herons**	small fish, amphibians, lizards and insects,frogs
2	*Ardea herodias*	Great blue heron	shrimp, crabs, aquatic insects, rodents, mammals, amphibians, reptiles, and birds
3	*Nycticorax nycticorax*	Night heron	*fish*, crustaceans, frogs, aquatic insects, and small mammals
4	*Botaurus stellaris*	Great Bittern	fish, eels, small snakes, salamanders, insects,frogs, crayfish, and small mammals
5	*Tachybaptus ruficollis*	little grebe	insects, larvae,**fish**, frogs, tadpoles, crustaceans, and mollusks.
6	*Ardea goliath*	*Goliath* heron	frogs, prawns, mammals, lizards, snakes, insects and carrion
7	*Ardea cinerea*	Grey Herons	fish, reptiles, amphibians, crustaceans, molluscs, and aquatic insects.
8	*Anastomus lamelligerus*	African open bill	terrestrial snail, frogs, crabs, fish, worms, and large insects
9	*Calidris alba*	Sanderling	Crabs, amphipods, isopods, insects, marine worms, small mollusks; also may eat some carrion.

Source: Field survey, 2019

Species of Conservation Interest

Conservation status of the species censored in the project area was conducted using the IUCN 2018-2 Red List of Threatened species. None of the sighted species censored in the study area were of conservation interest as all were categorised as Least Concern (LC).

4.11.4: Mammalian Studies

Species diversity

A total of four mammalian species were inventoried in the study. Two of the species (*Orcinus orca,* and *Stenella frontalis)* were sighted while *Trichechus senegalensis, Stenella longirostris* were inventoried through indirect evidences. *Orcinus orca, Stenella longirostris and Stenella frontalis* are in the order Artiodactyla while *Trichechus senegalensis* is in the order Sirenia

Species Frequency

The frequency of sighted species showed that the species were sighted in two locations each (Figure 4.11.3). *Orcinus orca* was sighted at 4.319590/6.53873 and 4.320272/6.578200 while *Stenella frontalis* was censored in 4.325202/6.564572 and 4.336290/6.427398. The areas are about 501 m and 516 m South of Kulakiri and Idegeba for *Orcinus orca* and 698 m and 392 of Opupopokiri and Negetekiri for *Stenella frontalis* respectively. The sighted mammals were observed in flocking in groups. Wole and Myade (2014) reported the existence of this species in Akwa Ibom while Weir (2010) reported the existence of this species in other Nigerian water bodies.

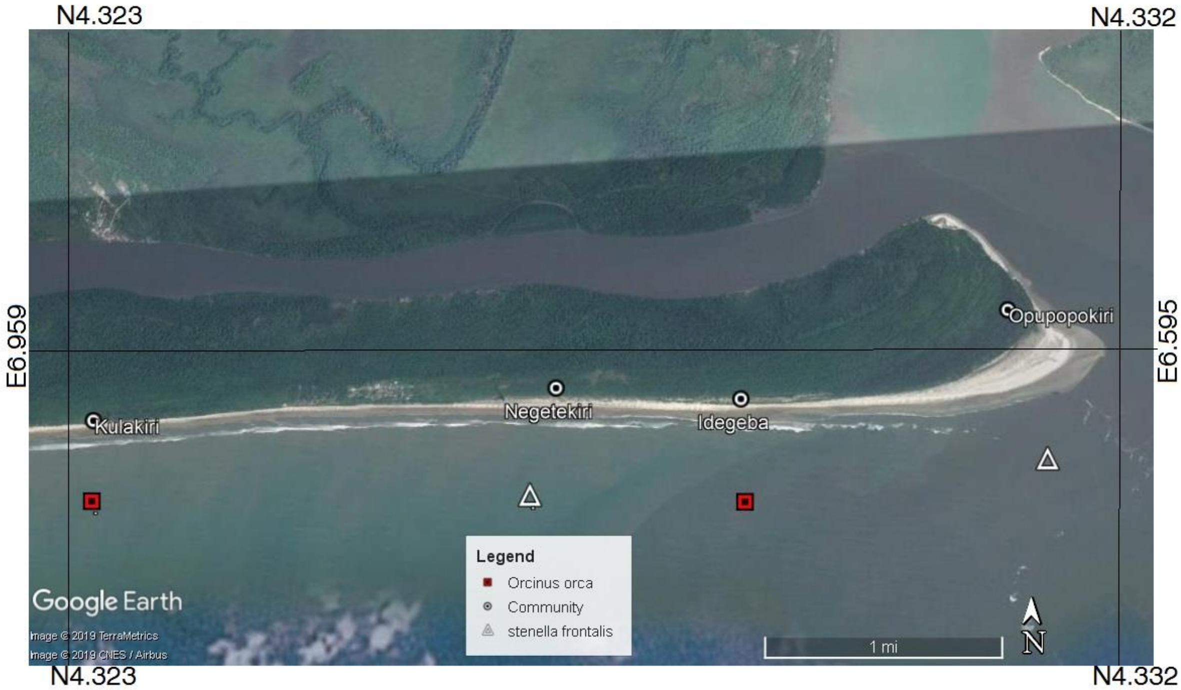


Fig 4.11.3: Locations of mammalian sightings during the study

Species Abundance

A total of three individuals of *Orcinus orca* were sighted with all flocking while one individual of *Stenella frontalis* (Plate 4.11.4) was sighted at the surface and the other swimming within the neritic zone.

Plate 4.11.4: *Stenella frontalis* displaying behavioural signals

Sighted Depth

The individuals of *Orcinus orca* were sighted at water depths ranging from 12 - 15 m and at locations near Kulakiri and Idegeba Brass while one of the two individuals of *Stenella frontalis* were censored at depth ranging from 7 m near Opupopokiri and the other at the water surface near Negetekiri.

Sex

The size of the dorsal fins was the sexual dimorphic feature employed to differentiate the genders of individuals of *Orcinus orca* while the sex of individuals of *Stenella frontalis* could not be determined. The two individuals of *Orcinus orca* sighted off Idegeba had dorsal fins lengths of approximately 3.6ft and 3.3ft implying same sex most probably female while the single individual sighted at Kulakiri had dorsal fins of approximately 2.4ft, suggestive of a male.

Time/tidal regime when sighted

The two individuals of *Orcinus orca* sighted at Idegeba were observed at around 15:55 hours while that sighted at Kulakiri was observed at around 12.35. On the other hand, the individual of *Stenella frontalis* sighted at Pupopokiri was observed at around 15:05 while the individual observed at Negetekiri was observed at around 18:13. Depth preference seems to correlate strongly with light intensity. It is probable that the species visit the epilimnion layers when light intensity is at minimum and dives to greater and colder depth during higher light intensity. Depth preference also seems to correlate with tidal influences. All individuals of both species were sighted at low tidal regimes. These findings suggest a species preference for calmer and less turbulence water regimes.

Behavioural Activity

Three behavioral activities were evaluated, foraging, travelling and resting. Both species frequently engaged in surface behavior such as breaching (jumping completely out of the water) and tail-slapping. These activities may have a variety of purposes, such as courtship, communication, dislodging parasites, or play. However, all the sighted individuals were seen travelling which may be in search of mating partners or moving away from unfavourable conditions (Carwardine, 2001).

Species indigenous uses

Both species are consumed locally as meat and as a source of oil, though they are not hunted in the region.

Food Habits

The reviewed food sources places both species in the top of the food chain haunted only by humans. The species food source comprises of the following: octopuses, seals, sea lions, smaller whales and dolphins, fish, sharks, squid, sea turtles, sea birds, sea otters, river otters, and other animals. *Orcinus Orca* uses many different techniques to catch prey. Sometimes they beach themselves to catch seals on land, meaning they jump from the water onto land. Orcas will also work together to catch larger prey or groups of prey such as schools of fish (Bradford, 2014).

Predators

Orcinus Orca have no natural predators, although young killer whales may be attacked by other killer whales or large sharks. They are at the top of the marine food chain. This species is not hunted locally. *Stenella frontalis* on the other hand is usually hunted by large species of whales. However, some fishermen gathered that juveniles of this species have inadvertently been caught occasionally by their fishing gears. A disease that affects *Orcinus orca* and is often studied is toxoplasmosis (*Toxoplasma gondii*). While this parasite is often benign, it can have serious and fatal effects (Chadwick, 2001; Murata, *et al*., 2004; Estes, *et al*., 1998; Heyning and Dahlheim, 1988; Mann, *et al*., 2000)

Conservation Status

The species is categorized as Data Deficient (DD) according to the IUCN Red List of threatened species and hence need be treated as a Threatened taxon in Nigeria; they are not listed in the Endangered Species Act 2016. Review showed that they are numerically abundant (at least tens of thousands of mature individuals) and very widely distributed. Killer whales inhabit all oceans of the world. Next to humans and perhaps the brown rat (*Rattus norvegicus*), killer whales are the most widely distributed mammals (Kachar *et al*., 2018).

4.12: Social Profile

4.12.1: Stakeholders Consultation

The project communities visited for the purpose of social impact assessment (SIA) included: Odioma, Ibidi, Obioku, Twon-Brass, Okpoama and Diema (Brass LGA, Bayelsa State); Kula (Kula, Macleankiri, Manakiri, Ibiapukiri, Elizakiri, Ilajakiri, Oyekiri and Idegeba) and Abissa (Abaji Okolo, Sangakiri, Torubiama, Angalabio, Tingibi and Ibrokiri) communities all in Akuku-Toru Local Government Area of Rivers state and Elem-Oproama (Opookolo, Abajioklokiri, Gold Coast, Okolo-Ogono, Otama, Ngeribarama, Bokokiri, and Eleme-Oproama), College Kiri (Francis Okpo-ama), Amakiri Konboko (Old Sangama) and Elem-Ifoko communities in Degema Local Government Area of Rivers State, Nigeria. The SPDC team, accompanied by the Community Relations Officer (CRO), representatives from the communities, Regulators, EIA consultants, the Media as well as community gatekeepers including titled Chiefs, Village Committees/Heads, representative of youths and women associations, community and faith based organizations (CFBOs) etc. were all consulted. To further consolidate the consultation engagement of the project, an open forum session was organized to sensitize the communities and other relevant stakeholders including Secretaries of Akuku-Toru and Degema Local Government Councils. In each of the communities visited, global best practice approach of community entry was deployed by first visiting the community leadership in order to gain their support and permit for successful data gathering and awareness creation for the anticipated project implementation.

Table 4.11.6: Stakeholders Communities in Study Area

	Stakeholder communities	LGAs	State
1	Odioma	Brass	Bayelsa
2	Ibidi	Brass	Bayelsa
3	Obioku	Brass	Bayelsa
4	Twon Brass	Brass	Bayelsa
5	Okpoama	Brass	Bayelsa
6	Diema	Brass	Bayelsa
7	Kula	Akuku-Toru	Rivers
8	Abissa	Akuku-Toru	Rivers
9	Elem-Oproama	Degema	Rivers
10	Old sangama	Degema	Rivers
11	Elem-Ifoko	Degema	Rivers
12	F- Okpo-ama	Degema	Rivers

Plate 12.1.1: Engagement sessions with the communities

4.12.2: Population Dynamics and Sociocultural Characteristics

Settlement History of Communities within the Proposed JK Drilling Project.

The study covered twelve (12) neigbouring coastal communities namely Kula and Abissa and their settlements (Akukutoru LGA of Rivers State); Elem-Oproama, College Kiri, Old Sangama, Elem-Ifoko (Degema LGA of Rivers State); Odioma, Ibidi, Obioku, Twon-Brass, Okpoama and Diema (Brass LGA of, Bayelsa State).

According to SPDC (2018), the settlement history of the Bayelsa communities was documented with specific reference to H-Block micro influence area, as contained in the Colonial Intelligence Report of the 1920s that the people of Obioku, Odioma, Ibidi, Twon Brass, Okpoama, are said to have migrated from Ogbolomabiri (Nembe) on account of a civil war. Unlike many other communities, Ikaba (The progenitor of Dieama Community) came from a place called Iselema – present day Itshekiri. He migrated to Oruamabiri to serve the King Deity of Nembe called OGIDIGA.

Kula community, it is one of the oldest settlements in the proposed project area. The settlement history of the people of Kula is traced back to the 13^{th} century. Kula community is made up of

14 independent settlements scattered around the present Kula territory-Opu-Kalu, Boro, Nangwo-ama, Kongo-ama kilama/Diaba/offo, Isoma, Ingeje, Owuagaye, Ibiame (Agudama), Tubo, Aiame, Oblame etc. The migration traditions of the Kula people can be briefly viewed in two broad categories; one group comprising a set of Ijaw (Ijo) settlers were traced to the Iselema area in Western Niger Delta while the other group comprising Sara and his people were traced to Engenni (of Delta- Edoid origin) in present Ahoada-West local government area of Rivers State. From Opu-kula, Sara moved Southward and after crossing the San Bartholomew River, Aguda Toru, founded the present Kula town which presently is the focal point of the ancient Kula kingdom.

4.12.3: Population Size, Growth and Distribution

Factors that could influence the population distribution of an area include environmental, natural resources availability and accessibility, migration, agriculture and commerce. Table 4.12.3 shows baseline population in the project area projected over thirty (30) years using 1991 census figures as the basis.

Table 4.12.3: Baseline Population of Stakeholder's Communities projected up to 2020

SN	Communities	1996	2006	2010	2015	2018	2020
1	Abissa	3262	4269	4867	5719	6320	6762
2	Kula	3837	44167	5905	6939	7668	8205
3	Ibidi	3486	4602	5048	5606	5940	6164
4	Obioku	3046	4021	4411	4898	5191	5386
5	Twon-Brass	17072	22535	24721	27452	29091	30184
6	Okpoama	17707	23373	25640	28473	30173	31306
7	Diema	1514	1999	2193	2435	2580	2677
8	Odioma	6777	8946	9814	10898	11549	11982
9	Elem-Oproama*	5000	6886	7826	9184	10109	10777
10	College Kiri*	300	413	470	551	607	647
11	Elem-Ifoko*	480	661	751	882	970	1035
12	Old Sangama*	750	1033	1174	1378	1516	1617

(**Note*:** population figures used for these communities are not from NPC but extracted from the FDG). ***Source: Computed by the Author, 2019***

Formula used to calculate future population figure: $Nt = Pe^{rt}$

Where:

Nt = future population

P = Base population (current population)

e = Natural algorithm (given as 2.71828)

r = growth rate (currently projected at 3.2% annually)

t = time projected

According to NBS (2017), Population projections are used for planning as well as calculation of future birth rate/death and migration of population based on their past and present conditions.

The annual growth rate used for the population projection was 3.2%. This result is consistent with the benchmark population density of 75 persons per hectare categorized as low density (Obateru, 2000). This result implies that, population may likely add severe pressure and competition on the existing resources and infrastructure in the study area. Previous reports (SPDC and Akpan (2018) revealed a marginal increase of 3.2% in population across the six (6) communities in the proposed project area. The fertility rates of Nigerian states (Figure 4.12.3) as obtained from NBS (2016) indicated that, Rivers State recorded the lowest fertility rate (3.3%) which is less than national average of 5.8%.

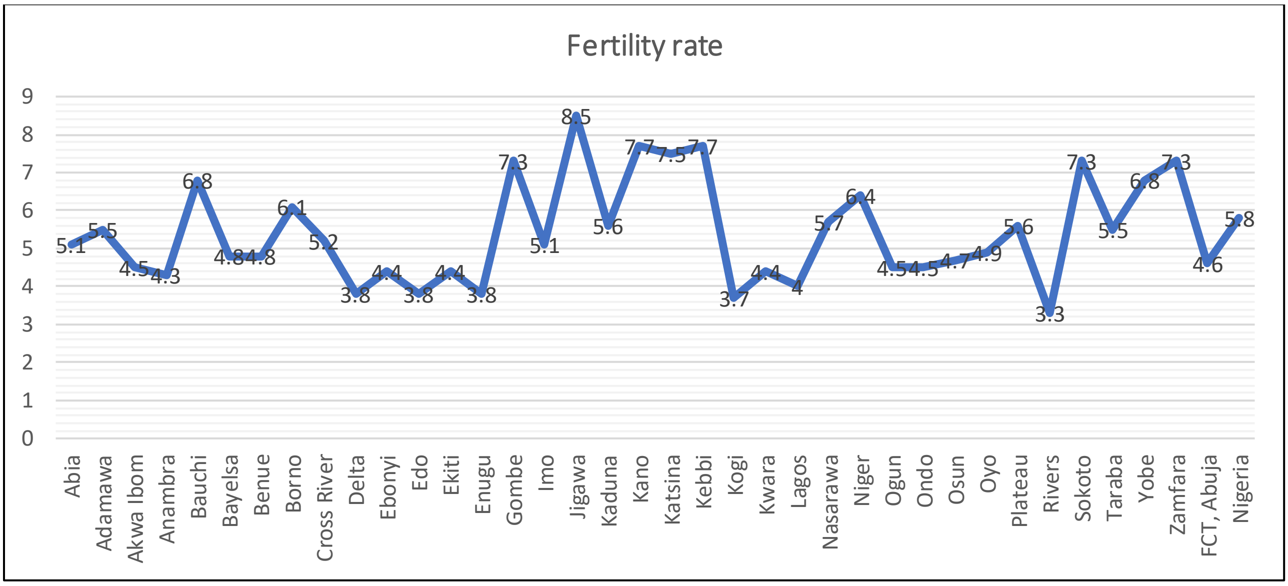


Figure 4.12.3: Fertility Rate in Nigeria, 2016

Population pattern in Akuku-Toru and Degema LGAs shows high population density in the urbanized upland areas such as Abonema, Buguma, and Bakana, . There are no major urban centres in the coastal areas of interest, although Kula is evolving due to plans by Belema oil to set up oil terminal operations there. Population in the coastal areas are largely concentrated in the main coastal communities such as Kula, Elem-Oproama, Elem-Ifoko etc. with dispersed population in the other settlements. Due to the dominant fisheries livelihood in these areas, there is seasonal population changes due to influx of fishermen to the settlements in the fishing season and emigration from the settlements back to the main communities in the 'rough' season usually during the rains.

4.12.4: Marital Status

The results of the marital status of the respondents in the project communities showed that, across the twelve project communities, over 51% of the respondents are married, 28% are single while the rest are grouped under divorced or widowed (Figure 4.12.4). This result implies that, greater number of the respondents are living together as families sharing common goals and responsibilities. It also reveals a stable society. From FGD sessions, it was found that most respondents with single status households in the study area were migrant workers and the unemployed including students.

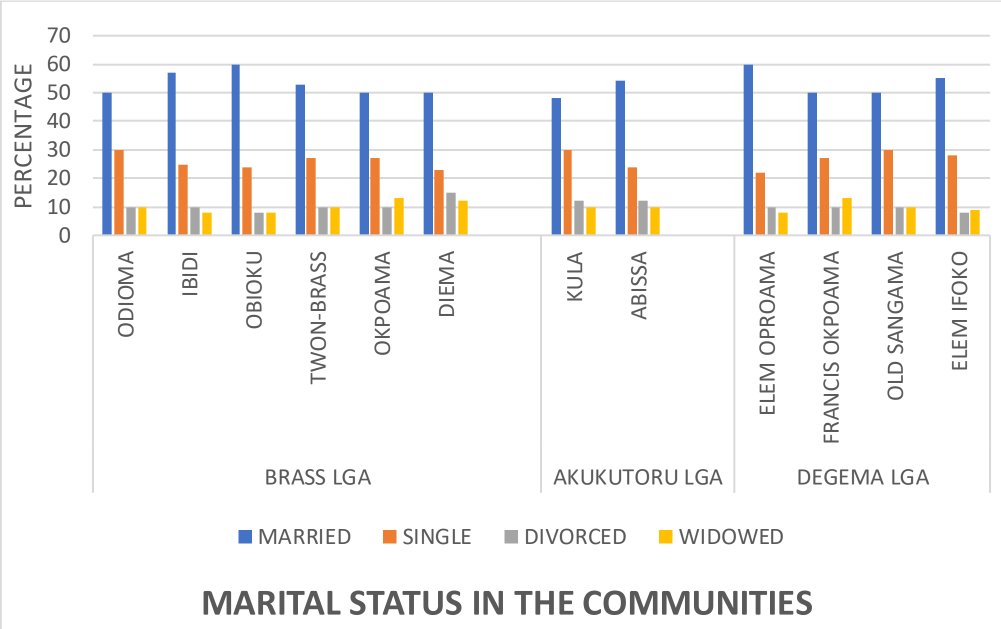
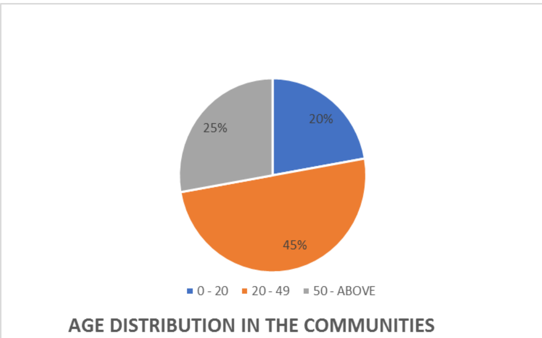


Figure 4.12.4: Marital Status

4.12.5: Distribution of respondents by age and sex

According to the National Population Commission (2016), Nigeria has an estimated population of over 193 million people, an annual population growth of 3.2% with over 41% below 15 years of age. Figure 4.12.5 presents the age and gender distribution of the respondents in the project communities. About Forty five percent (45%) of the respondents are 20 - 49 years of age. Those with age less than or equal to 20 and greater than 50 years represents 20 and 25% respectively. This shows a dominantly young population.



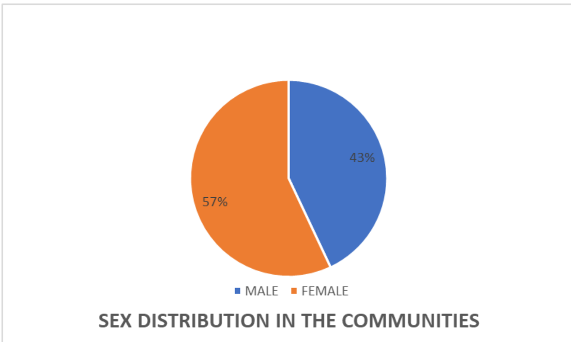


Figure 4.12.5a and b: Age distribution in the communities and Sex distribution in the communities

It was estimated that about 57% of the population are females while 43% are males. Despite this, the result shows a patriarchal as well as a male dominant governance structure across the communities.

4.12.6: Distribution of Respondents by Household Headship

The distribution of respondents by household headship is presented in Figure 4.12.6. The result shows that over 60% of the households in the study area are headed by males while 40% are female headed households. During FGD sessions, some discussants linked the seemingly high number of female headed households to killings of men during occurrences of inter-ethnic and communal disputes and wars. Previous studies by SPDC (2018), Akpan (2017) and Niger Delta Report (2010) showed that 93% were male-headed households against 7% for female-headed households. This agrees with Ojide (2010), and Akpan (2018).

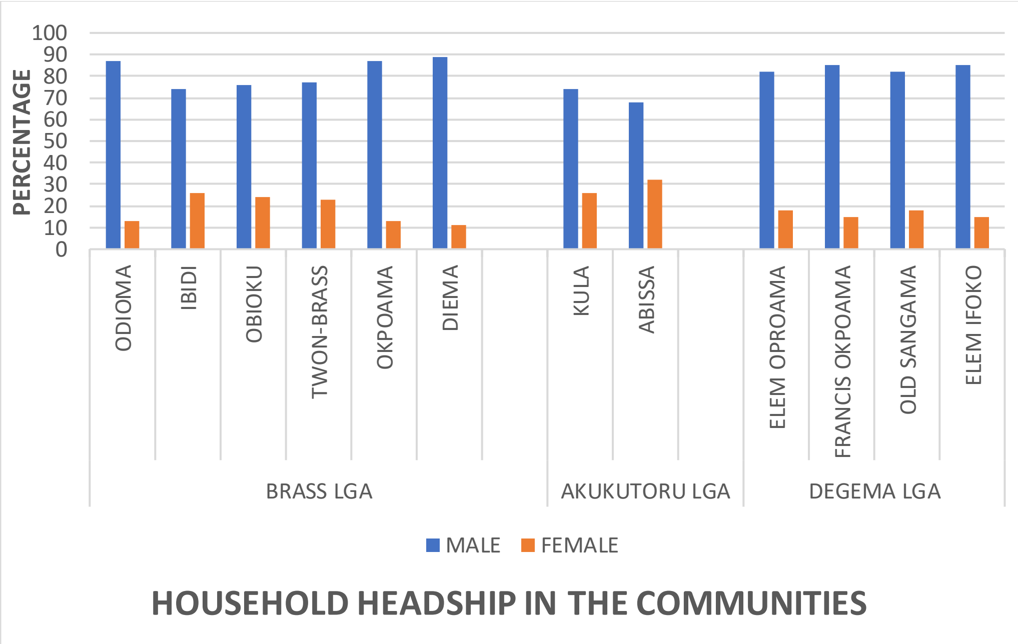


Figure 4.12.6: Distribution of Respondents by Household Headship

4.12.7: Distribution of Respondents by Educational Attainment

The level of educational attainment in the Niger Delta Region is shown in Table 4.12.7. Adult literacy is over 70% across the States while attainment of primary education is above 15% in some states (Rivers – 17.1%, Delta – 18%, Abia – 16.8% etc).

Table 4.12.7: Level of Educational Attainment in the Niger Delta States

State	Adult Literacy (%)	Attainment of pri. Sch. (%)	Attainment of sec.sch (%)	Attainment of Post sec. Sch. (%)	No. of Jobs in Sector (2000)
Abia	84.1	39.6	43.6	16.8	9.276
Akwa Ibom	76.3	54.4	44.4	8.3	13.683
Bayelsa	78.7	38.8	49.3	11.9	3,525
Cross River	82.2	44.6	42.8	12.6	11,425
Delta	77.4	37.9	43.6	18.5	15,720
Edo	69.7	49.3	38.8	11.9	10,959
Imo	79.3	46.1	42.7	11.2	14,145
Ondo	78.8	45.0	44.2	10.8	12.342
Rivers	79.9	33.4	49.5	17.1	4.011
The Region	78.7	43.3	43.2	13.5	95,076

Source: Niger Delta Regional Development and SPDC (2017)

Results obtained from present study (Figure 4.12.7) shows adult literacy in the study communities was above 60% with over 80% of the population haven completed either primary, secondary or tertiary institutions. Over 40% of the respondents attended and completed secondary education across the communities, 35% attended and completed primary education, 20% attended vocation/technical as well as colleges of education and polytechnics while 5% attended and completed university education. The study linked the improvement in educational attainment in the area to SPDC, State/Federal Government, NDDC, NGO's and private sector investment in education. It was also observed that sport facilities were provided by SPDC and its in use by the students. This finding is consistent with similar studies conducted in the Niger Delta by Umoh, (2017). However, FGD reveals a high dropout rate from primary (45%), secondary (30%) and 25% at tertiary levels due to a number of factors including accessibility, availability and affordability of education at all levels. It was also gathered that low income status of the people hindered the possibility of meeting educational needs in private and public schools in the study area.

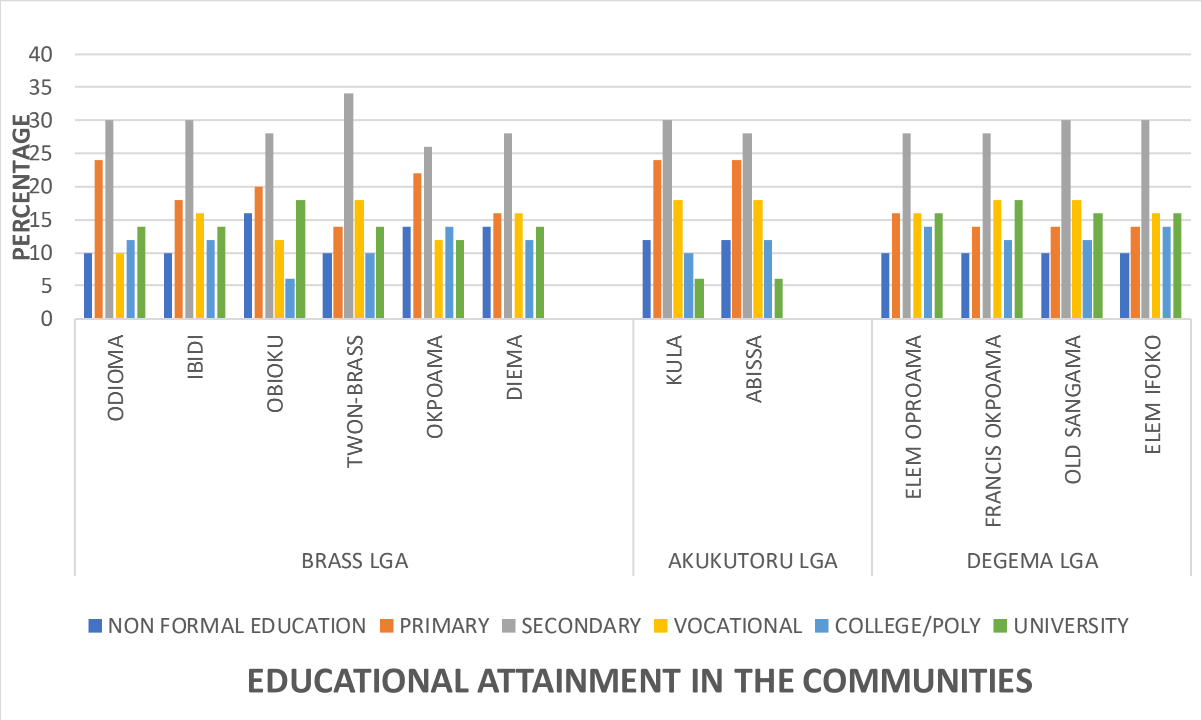


Figure 4.12.7: Educational Attainment / Literacy Status in the study communities

Net Enrolment on Primary and Secondary School Levels

The goal of the Universal Basic Education in Nigeria is to enhance access to free and compulsory education up to the junior secondary school level (UBE, 2010). Figure 4.7.6 presents the net enrolment rate in primary and secondary school (junior) levels in the Niger Delta region. It shows that across the states net primary enrolment rate is higher than the secondary enrolment. Over 700,000 are recorded in Akwa Ibom followed by Bayelsa, Edo and Rivers. Bayelsa State recorded the least in terms of net enrolment in secondary school but higher in Rivers State compared with Cross River. Similar trends were observed across the twelve communities in the proposed project area. In-depth interview with teachers in the communities, revealed that, net primary enrolment rate was higher than net secondary enrolment.

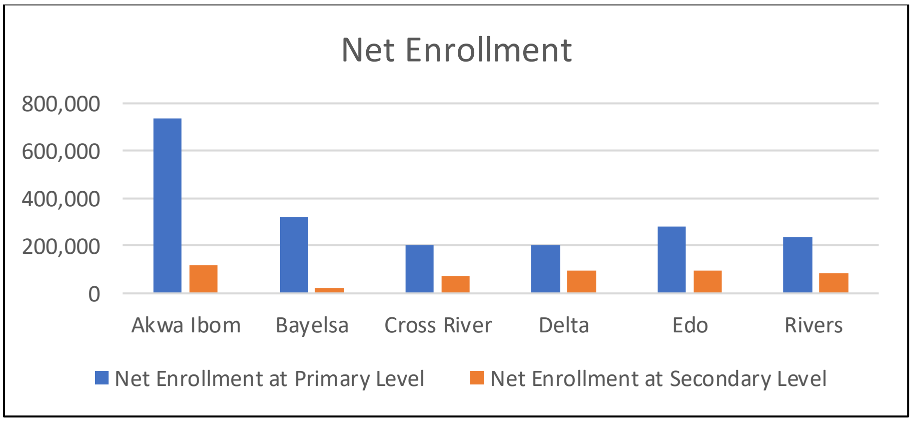


Figure 4.12.8: Educational Enrolment in the study area

The low net enrolment rate in both primary and secondary levels was attributed to inadequate educational facilities, such as school blocks, long distance and high cost of transportation to the nearest school facilities; this is consistent with previous reports in the area (SPDC, 2011; 2018).

4.12.8: Distribution of Respondents by Household Size

The National Bureau of Statistics (NBS) and United Nations Development Programme (UNDP) Standards were used to determine household size in the study area. Result of the household size study (Figure 4.12.9) shows that 56% have between 5-8 persons ; 30% have 1-4 persons and 14% have 9 persons and above in a given household. This result is consistent with NDDC (2003), Ojide (2011) and SPDC (2018) that gave average number of persons per household in the area as 8 persons. Result further shows that average household size in the region is six persons with considerable variations among the states and local government areas. The high household size was linked to resource availability, job opportunities as well as trade and other commercial activities in the study area.

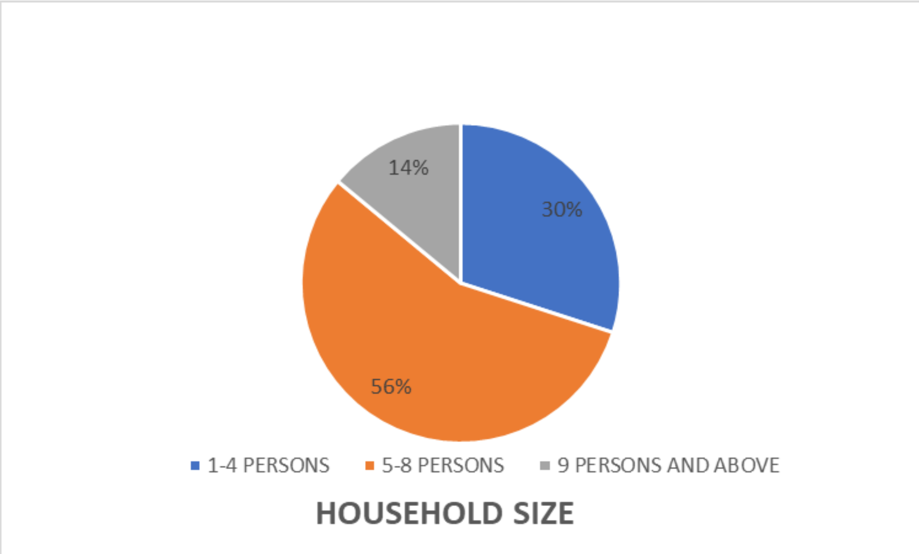


Figure 4.12.9: Household size

Distribution by Dependency Ratio

The study assessed the dependency ratio across the twelve communities. Dependency ratio as used in this study described the pressure an economy faces in supporting its non-productive population. The higher the ratio, the greater the burden being impose on the productive population. Results showed that 88% of the population depend on only 12% of the active labour force in the study area (Figure 4.12.10). This implies a large number of unemployed or under-employed across the study area. Information gathered from the FGD session revealed that there is a greater burden in supporting the aging population.

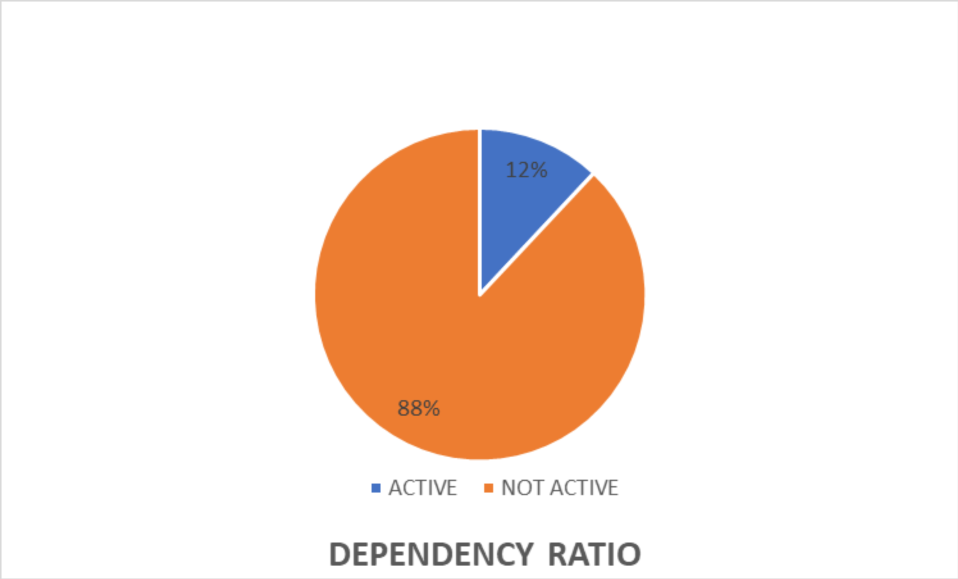


Figure 4.12.10: Dependency Ratio in the Study Area

4.12.9: Migration status in the Study Area

Human migration is an important demographic variable that require frequent checks and analysis. It is one of the causes of major national and internal disputes. Migration in the study area is a common phenomenon considering the settlement histories of the communities. The rate of immigration (movement into the communities) is about 60% while emigration (movement out of the communities) is 40% respectively.

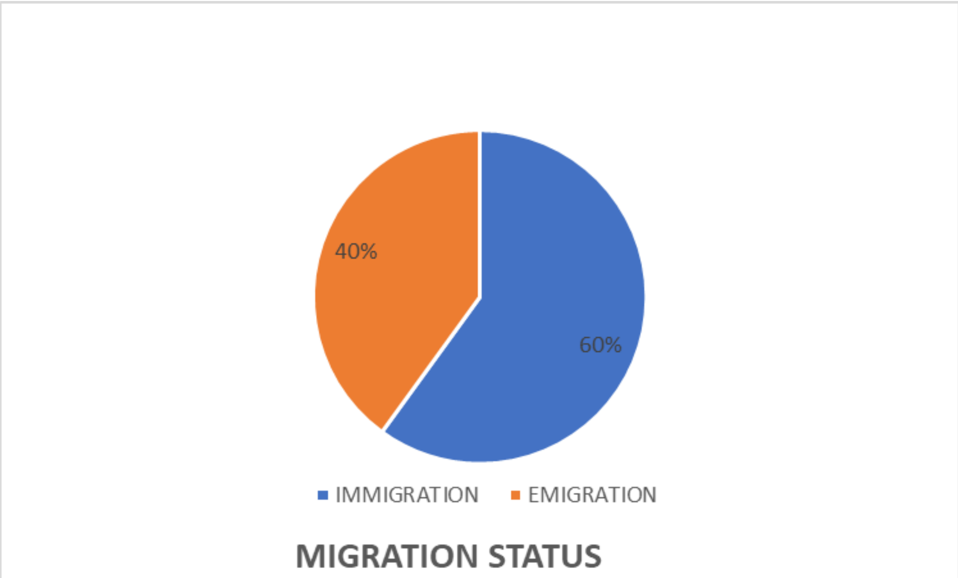


Figure 4.12.11: Migration Status in the study area

4.12.10: Pressure on Existing Infrastructure

Information obtained during the reconnaissance field survey and FGD sessions in the project communities, revealed an increase population which was linked to increased child birth in the project area. This has exerted pressure and competition on infrastructural facilities (housing, education and health, roads and electricity, etc) and land among others. Figure 4.12.12 presents the level of pressure exerted on infrastructures and resources in the area. Over 85% of the respondents agree that, households, firms, individuals, and communities jostle for power and access to the available infrastructures in the area. This is evident in incessant crisis and conflicts emanating from these actions. Similar results were obtained in previous studies in the area (SPDC, 2011, 2010, 2009, 2008; Akpan, 2014). Available information shows that the population of Nigeria has increased by about that 268% during the last 50 years from 45.2million in 1960 to over 170million presently. This high rate of population growth has placed a huge strain on the country's infrastructure.

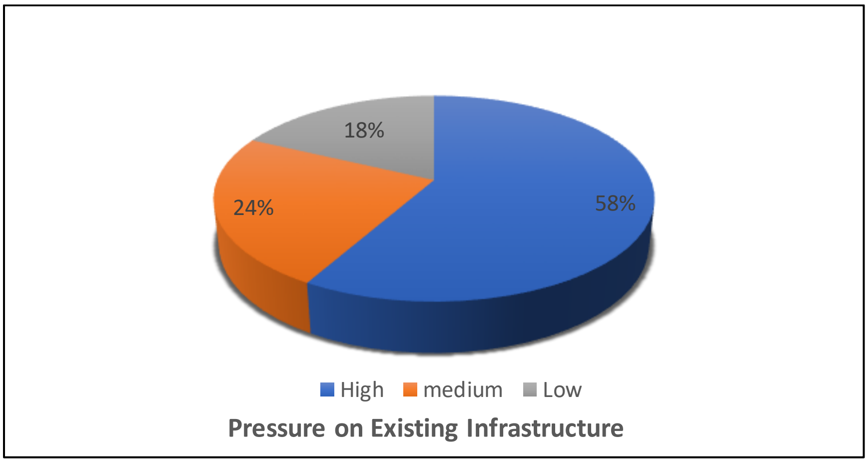


Figure 4.12.12: Respondents' perception of level of pressure on existing infrastructure

4.12.11: Religious Affiliation in the study area

Figure 4.12.13 presents the religious affiliation of the people in the study communities. It shows that majority (over 80%) are Christians while 5% and 15% are Muslims and traditional worshipers respectively.

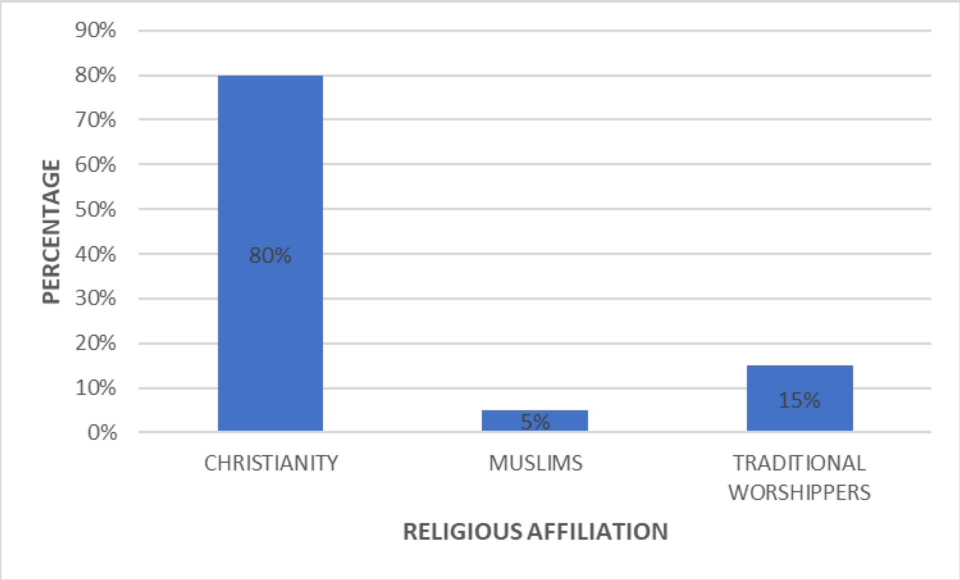


Figure 4.12.13: Religious Affiliation in the study communities

SPDC (2019) stated that it is crucial to hold in reverence the reminiscence of ancestors and religious traditions. The study identified Owuamapu as one of the prominent or water spirits (idol) in the project communities. In the study communities, there is increase presence of Muslims due to expansion in livestock trade in the area.

The result agrees with SPDC (2014 and 2017) which reported that there were only few adherents to African traditional religion (ATR) in the Niger Delta although a handful of members of these communities still practice ATR and most members in the communities participate in traditional festivals linked to the ATR. Across the communities, the study found that there are communal deities and shrines, sacred bushes, sacred streams/creeks etc. Some of the deities and shrines are communally owned while others are owned by certain families (Table 4.12.10). During FGD sessions, it was gathered that associated with these deities and shrines are annual festivals, rites and rituals which define the traditional religious worship, practiced in each community. The festivals are said to serve important spiritual purposes such as warding off evil, promoting fertility in marriages, profitable enterprise in fishing, and farming among others.

Table 4.12.10: Deities mapped in some of the Project Communities

Community	Deity/Shrine	Location	Distance to Proposed Project
Abissa and Abaji Okolo	Akia	Community	Not on proposed project site
Kula	Agba	Community	Not on proposed project site
Elem Oproama	Orubio Bokolo,	Community	Not on proposed project site
Old Sangama	Asari, Konibo, Opu ada, opueze, seki opu	Community	Not on proposed project site
Twon-Brass	Seven sisters' shrine and forest	Community	Not on proposed project site

Source: FGD with Stakeholders.

In College Kiri (Francis Okpoama), the people stated that they do not have shrines. In Twon-Brass community, there are other significant historical sites such as the cemetery of the early white visitors and the tomb of the first *Amanyanabo* of Ada Ama in the village square.

4.12.12: Culture and Tradition

Cultural practices include festivals and masquerade dances (Table 4.12.12). These festivals are marked with feasting and merry making. Some of them like Feni in Sangama and Agba in Kula celebrate communal deities; this is the same with other study communities. There are a number of sacrifices and general reverence for traditions and festivals associated with traditional worship.

Table 4.12.12: Cultural Festivals in some of the Project Communities

Community	Festival
Abissa and Abaji Okolo	Odofara (June yearly)
Kula	Agba (November yearly)
Twon-Brass	Abadiyai Annual festival
Okpoama	Idumangi Olali (every seven years)

Source: FGD with Stakeholders

	
A	b

Plates 4.12.12: Predominant fishing festival and Dance in the study area

Cultural Prohibitions/Taboos

The communities have common cultural prohibitions which include killing and eating of snakes (pyhton), sheep and eagles. If anyone, including project workers, kills a python the person must organize a full burial for the it. The burial must be performed with all burial rites, as traditionally required for the burial of a human being. The communities do not eat mutton or allow sheep or mutton to be brought into the community. Apart from language, deities and festivals another major cultural heritage is Ekinesekiapu socio-cultural group. This group is present in Kalabari communities and in all the study communities. The Ekinesekiapu socio-cultural group serves as custodian of the traditions and customs of the people and its role is to enforce traditional rules and sanctions.

4.12.13: Traditional Marriage

There are two types of marriages among the Kalabari Kingdom including the project communities, namely igwa and iya. With igwa, the groom meets the parents of the bride and presents drinks and is ‘allowed’ to live with the bride and even to have children. This practice is accepted in the society but it is not a full marriage; it is more or less a temporary and private arrangement because the community is not part of the process. Traditionally, children born in igwa marriage do not have inheritance claims over their fathers’ properties or family inheritances. But with iya marriage, relatives, extended families or compound and the larger community (village/settlement) are invited. Gifts, especially drinks, wrappers and cash are presented by the groom and his family to the bride, the bride’s parents, extended family and the community. It is a community wide celebration and also notification that the bride is married. The ceremony involves the determination of a dowry which is usually a token and a traditional practice called bibife. Bibife requires that the bride’s family is feasted to a sumptuous meal which will include traditional meals like onunu and fresh fish pepper soup. It binds the relationship and implies that the bride’s family can eat in the couple’s house. Some individuals and families insist that they will not eat in the couple’s house unless the bibife ceremony is performed for their daughter (Plates 3a and b). With iya, children born to the couple have full claims to their fathers’ properties and inheritances. Despite the type of marriage, the Kalabari have a tradition of returning the corpse of a wife to her father’s compound for burial. The groom is notified at the time of marriage that he is only marrying the body and not the bones (Plate 4.12.13).

		
a	b	c

Plates 4.12.13: Scene and sites of traditional marriage ceremony in the study area

Family and Inheritance

The communities have nuclear and extended family structure. The nuclear family is made up of the father, mother and children. Sometimes, children also refer to wards that may include children of relations and friends. Each extended family has a common ancestral heritage. A group of extended families forms a compound and a war canoe house in some cases. The war canoe house was traditionally a trading unit able to muster arm and command a war canoe during wars. It is common to other Ijaw communities in the eastern Niger Delta including Nembe, Okrika, Bonny and Opobo. Traditionally, children inherit their fathers' properties. Usually, the first son and other sons have a prominence in family inheritances.

4.12.14: Political Structure and Governance

Traditional Governance System, Power Structure Social Organisations

Results of Focus Group Discussion sessions across the twelve (12) project communities studied reveal similar traditional governance structure and system that is peculiar to the Ijaws of the Niger Delta Region. The people operate both formal and informal system of governance. The formal system is the presence and subjection to local, state and federal governance structure. At the apex of traditional governance in each community is the Village Head. Each community has its village council with chairman that work hand-in-hand with the village Head. There are also family and clan heads who preside over the affairs of their families and clans. The clans are composed of a few to several villages but share the same history. The traditional leadership and governance system in the project area is structured into hierarchies with about five (5) functional organs namely – the Amanyanabo who is the paramount king or chief, Clan Heads, Village Heads, Executive Council, Youth Executive Council, women Association, Community Development Committee and Several Community and faith based organizations (Figure 4.12.14).

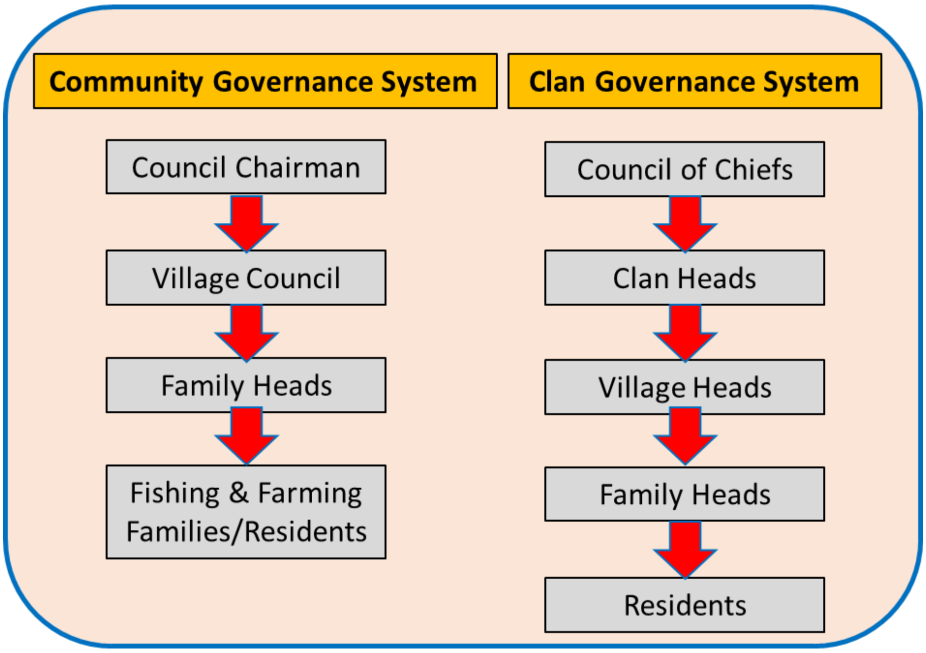


Figure 4.12.14: Traditional/Political Governance structure @ the Clan level.

The Paramount Ruler and his traditional Council of Chiefs wield much influence in the traditional governance in the area and must be consulted for any successful project implementation. The traditional institutions in the communities are very strong and have remained stable over time. During consultation with the community gatekeepers (chiefs, adult males and females and the youths), it was revealed that, there are strong Community Development Committees in all the project area. According to SPDC and Akpan (2019), the committees work in synergy with the community's structures to promote peace, project initiation and implementation, provide security to community and public facilities and enforce law and order in the project communities. The respondents affirmed that, there is harmonious relationship between the coastal communities and SPDC over the years despite few disagreements on some issues.

The tenure of the Village Heads and Paramount ruler is for life. They are succeeded only at death. The selection of new Village Head is done by the council where they usually meet. Plate 4.12.14 shows typical traditional palaces and Council Halls respectively where Council meetings are held. Plate 4.12.15 shows the symbols of legendry authority in the Ijaw kingdom.

Plates 4.12.15: Symbols of Legendry Authority in Ijaw Kingdom

Succession Issues

According to SPDC (2019), communities in the Niger Delta upholds the tenure of traditional rulers (Paramount Rulers, Clan/District Heads and village Heads) for life. They are succeeded only when they pass on through transition. In the case of a Paramount ruler, special rites are usually undertaken during the selection and the candidate that finally emerges is always from the ruling or Royal family. Following the demise of the Village Head, it is the responsibility of the Village Council to choose (among their kindred's) the candidate to succeed. There are changing dynamics in the positions of the village chairmen and community executive councils. For instance, the tenure of the community executive council (in most cases) is three (3) years while the youths and women leaders have two years term respectively. Also, there are guidelines regarding their operations and activities. However, if any executive member of the council or associations errs or violates the principles guiding the association as provided in the constitution, he/she could be removed from office and may face sanctions by the members. Study reveals that the position of the Treasurer is reserved for the women in the community executive council. According to Akpan (2017) the women associations headed by their executives played important roles in the development of the community in the areas of sanitation, commerce, child bearing and upbringing, farming, fishing, value re-orientation and education among others. The study also observed the existence of community and faith-based organizations who work to maintain family, community and inter-community cohesion. Umoh (2017) reported that, in most cases, if the succession process is not properly managed, it leads to serious tension and conflicts.

Emerging Power Brokers in the Communities

There are levels of influence on the constituted traditional governance structure in the project communities. The study identified emerging groups that seemingly wield enormous power in the area. During group discussion and consultation meetings with the communities, it was observed that, community executives/village councils, youths and women association executives are very forceful and actively participate in community issues and decision making. The emergence of militancy and other youth restiveness is an example of outburst of new power broker in the Niger Delta region. There are strong youth socio-political organizations as well as the vigilante groups that work with the village chairmen and Village Heads to ensure that civil laws made by the Village Councils are effectively enforced including security of lives and properties as well as oil facilities of multinationals. Women association was identified to have great influence on community affairs. This was seen in all the communities surveyed. Interestingly, faith-based organizations (FBOs), religious leaders of different church denominations were also identified as having so much influence on their followers. Most family issues between couples are settled by their Pastors as most, especially women rely on them for counselling. Some respondents affirmed roles played by juju priest as vessel for problem solving and consultation.

Prevailing Situation/Relationship between the Traditional Leadership and Modern Governance Institutions–Federal, State and Local governments administration.

The study deduced that, there is strong relationship existing between traditional (informal) leadership and the modern (formal) governance institutions in the study area. There is synergy in governance structure as identified in the three (3) tiers of government namely local, state and federal government. The closest government to rural populace especially the project communities is the local government. Some studies have shown that, traditional leadership has a stronger link to local governance institution than the state or federal (National) government. As applicable to other states in the study area, village and Clan Heads obtain their certificates of recognition and staff of office from the state government after due facilitation by the Ministry in charge of Chieftaincy affairs of the state. This framework enhances effective administration in the project communities. This relationship has brought about peace as well as busting criminal elements in the communities. Similarly, the relationship has been strengthened by oil exploration activities in the study area which necessitated frequent meetings between the communities, local and state government and the community Relation Officers (CLOs) to mitigate conflict and stem youth restiveness. The local and state government rely on the traditional leadership to enforce civil laws and maintain order in the communities. This is achievable through regular interface between the traditional institutions and the local as well as state and federal government through their representatives.

4.12.15: Conflict Management, Avoidance and Resolution Mechanisms

Prompt conflict identification, management, avoidance and resolution mechanisms are very crucial in the project area. According to Okoh (2005), the Niger Delta region has witnessed an unprecedented spate of violent conflicts in the recent past, and all efforts to quell the conflict seems to have failed to yield the desire results. Table 4.12.15 chronicles some of the major conflicts related to oils and gas activities in the Niger Delta area. Some studies (UNDP, 2010; Ukoh, 2010; Social Action Briefing, 2011 and Akpan, 2018), reported that, conflicts in the Niger Delta communities commonly fall under four (4) categories namely, intra-community, inter-community, inter-ethnic and between community and oil companies. Table 4.12.16 presents some identified inter-communal conflicts in the area while Table 4.12.17 presents cases of intra-communal conflicts in the area.

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Table 4.12.15: Trend of conflicts in Niger Delta (including selected communities of the proposed project)

S/N	Date	Community/LGA	State	Cause of action	Outcome
1	1971-1996	Niger Delta	Bayelsa State	Oil Spills and Pollution	Statistics from the DPR indicates that between 1976 and 1996 a total of 4835 incidents resulted in the spillage of at least 2.446,332 barrels (102,7 million US gallons)
2	1971	Ejamah-Ebubu (Ogoni)	Rivers	Oil Spill	Destruction of farmlands threatening flora and fauna
3	May 8, 1997	Elele Alimini	Rivers State	Oil Spill at Mininta Rumuekpe Pipeline	Oil production generates conflicts, large area of farmland, fishponds destroyed. Shell alleged it was caused by the tenant family.
4	March 27, 1998	Jones Creek Flow Station	Delta State	Oil Spills at Jones Creek Identified by Shell as pipeline failure	20,000 barrels (840,000 U.S gallons) killing large number of fishes
5	1987	Iko	Akwa Ibom	Series of disturbances in Iko following a protest against Shell	Mobile Police burnt down 40 houses
6	October 30-31, 1990	U-Muechem-Etche	Rivers	Protest by youths against total neglect by SPDC and Government of Nigeria	The community was razed by mobile policemen. Over 100 people were killed and 495 houses destroyed
7	October 1998	Jesse	Delta	Pipeline explosion	More than 1000 people died
8	July 2000	Adje near Warri	Delta	Pipeline explosion	Several hundred people died
9	November 1999	Odi	Bayelsa	That on November 4, 1999 and armed gang killed seven Nigerian policemen in Odi	Soldiers moved into Odi and razed the community, 2483 people, including women and children died
10	July 10, 2005	Ikarama-Yengoa LGA	Bayelsa	Oil Spill	Serious impact on the flora and fauna including their arable land and swamp.
11	February 19, 2005 (saturday)	Odioma	Bayelsa	Payment of compensation to Bassambiri instead of Odioma by shell petroleum Development Company	More than 18 people were killed
12	July, 2005	Bille Protest	Rivers	The community, said that for 45	Ecological violence through environmental pollution,

S/N	Date	Community/LGA	State	Cause of action	Outcome
				years shell has been prospecting oil and gas in their locality and that they have nothing to show for their economic contribution to the nation (Nigeria) except impact.	destruction of the ecosystem, health problems
13	October 14, 2000	Olugbobiri Southern Ijaw	Bayelsa	Unarmed youths approached the Tebidaba flow station to protest the failure of NAOC to complete certain agreed projects in the Olugbobiri community	Soldiers and Naval personnel at the flow station opened fire on the boats conveying the youths, 8 were killed and another died later in hospital. Several bodies were not recovered and more than 16 persons were injured.
14	January 1999	Ikeremor Zion, Opia and Ikenya	Delta	Armed soldiers aided and abetted by Chevron Nigeria limited raided the communities belonging to the Ijaw people.	The communities were burnt down leaving several people dead and injured
15	January, 30 1999	Ogulagha	Delta	Youths demanding for employment in recognition of the Kaiama declaration.	Many youths were shot and 19 died with many injured
16	May 17, 1999	Kokodiagbene	Delta	Soldiers escorting shell barge	Killed two youths of the Ijaw extraction
17	May 28, 1998	Parable platform	Ondo	120 youths from llaje community went to the Chevron offshore drilling facility known as parable platform where they requested to meet with Chevron officials to demand compensation for environmental damage caused by canals cut from Chevron	Nigeria Navy and Mobile Police fired the demonstrators killing two people. Jolly Ogungbeje and Arolika Irowarinum.
18	December 2003	Rukpokwu-Obio-Akpor LGA	Rivers	Oil Spill	Fish ponds, farmlands and livelihood are seriously devastated
19		Ekeni-Ezetu	Bayelsa	Non implementation of MOU by Texaco	Chevron-Texaco operates here.

Source: *Compiled from various sources 2018 and SPDC, 2019*

Table 4.12.16: Inter-Community Conflicts in the Niger Delta Region

SN	Communities Involved	Causes	Year
1	Bassambiri and Ogbolomabiri	L.G.A (location of Headquarters)	1997
2	Akassa and koluama	Land dispute	2002
3	Ogu and Bolou	Land dispute	2000
4	Ke and Bile	Land dispute	2001
5	Eleme and Okirika	Land dispute	2001
6	Okirika and Ikwerre	Land dispute	
7	Illajes and Ijaws	Territorial/land dispute	1999/1998
8	Ijaws and Itsekiri's	LGA Creation/ Ward creation/Territorial/land dispute	2000/2004/1991
9	Andoni and Ogoni		1970/1974/1998
10	Urhobo's and Itsekiri's		1997/1998
11	Akassa and Egweama		2000
12	Biseni and Okordia	Land/Oil field	2002
13	Epedu Versus Emadike	Land	1999/2000
14	Amabolou and Ayama		2001
15	Ekeremor and Ogbodobiri	Privacy Issue	2004
16	Okpoama and Ewoama	Chieftaincy	1998
17	Biogbolo and Yeneizue	Land	2001
18	Okpoama and Twon-Brass	Land	1999
19	Peremabiri and Diebu		
20	Oluasiri (Nembe) and Orusangama (Kalabiri)	Territorial/land dispute	1994/95
21	Oleh Versus Olomoro	Oil field dispute	1999
22	Beletiema Versus Liama	Murder of a Woman	1997
23	Opuama and Ofonibiri		2000
24	Okuruama Versus Abuloma	Murder of a Woman	2005
25	Apoi Versus Agip	Oil Spillage	2003
26	Choba Youths Versus Wibros	Social amenities	2000
27	Egi youths Versus Agip	Social amenities	
28	Black Markets Crisis Youth Versus Military		
29	Okpoama-Turu Versus Agip	Social amenities	
30	Tebidaba Versus Agip	Social amenities	
31	Ikebiri Versus Agip	Social amenities	1998
32	Ojobo Versus shell SPDC	Violation of MOU. Social responsibilities	1998
33	Gbarain Versus SPDC	Social amenities	1992
34	Gbarain Oil Field owner versus SPDC	Environmental Impact Assessment (EIA)	1994
35	Gbarain Community versus SPDC	IOGP (EIA)	1992

SN	Communities Involved	Causes	Year
36	Rukpokwu versus SPDC	Oil Spillage	2004
37	Epie communities versus SPDC	Oil Spillage	2003
38	Elekahia Youths versus Nkpogu Youths	Social responsibility	2000
39	Niger Delta Peoples Volunteer	Resources control, self-determination, convocation of national conference	2004
40	Niger Delta Vigilante versus Niger Delta Peoples Volunteer Force	Protection of rights	2004
41	Obioku versus Odioma	Murder of twelve persons	2005
42	Olugbobiri vs Ologboro	Oil well field	2002
43	Opuoma and Oforibiri	Land dispute	2000

Source: Nengi (2015), Akpan (2018) and SPDC (2019)

Table: 4.12.17: Intra-community conflicts in the area

SN	Communities involved	Causes	year
1	Ikanyabiri	Chieftaincy Tussle	2004
2	Ekeremor	Community Development Committee Leadership (CDC)	2004
3	Olugbobiri	CDC Leaders	2004
4	Epebu	Youths Leadership tussle	2004
5	Bassambiri	Political groups	2003
6	Imiringi		2000
7	Peremabiri	Control of Community resources (several persons killed, houses burnt etc)	2000
8	Isongufuru versus Teme (Nembe-Ogbolomabiri)	Several killed/houses burnt	2000
9	Igbomotoru (Intra)	LGA Headquarters location	2001/2002
10	Enewari	Houses Burnt/destroyed	
11	Kalabari	Kingship Tussle	2000
12	Opobo	Kingship Tussle	Settled
13	Ogbakiri	Several people killed, houses destroyed	

Source: Adapted from Nengi James Op. Cit, and SPDC (2019)

Studies revealed that, there has been increasing youth restiveness in communities within the region. Communities have come into conflict with oil companies, with each other, and with the security forces over a range of issues including payments of compensation for land acquired and for environmental damages caused by oil exploration activities. Proliferated armed groups have waged systematic campaigns against the government, oil companies and other donor agencies to have their demands met. Poverty, oil spillage, neglect of stakeholders communities by oil companies, high rate of unemployment, gas flaring, lukewarm attitude to infrastructural development including roads, jetties, school blocks, health facilities, electricity, skill acquisition centres, failure to implement planned activities in the memorandum of understanding (MoU), non-compliance with court orders and rulings, poor communication as well as intimidation were identified as triggers and causes of conflicts in the project area communities. Table 4.12.18 presents typical causes of conflict and resolution mechanism in the study area.

Table 4.12.18: Conflict profile and resolution mechanisms across project communities

S/N	Type of Conflict	Major Causes	Resolution Mechanisms
1.	Conflict within families	Poverty, unemployment and marital infidelity, kids	Family Head through dialogue
2.	Conflict between families	Power and authority, property sharing and rights	Family Head by dialogue.
3.	Conflict within communities and interest groups	Leadership tussle, resource sharing, sectional/family dominance and marginalization	Dialogue
4.	Conflict between communities	Resource ownership mainly water, land and forest reserves)	Dialogue/Conflict
5.	Conflicts between communities and companies	Not honouring MOU agreement, slow pace to community development	Dialogues and/or court ruling
6.	Conflicts between communities and government	Inadequate (lack) of infrastructural development projects.	Dialogue/Court ruling

Source: Field Survey, 2018

The study shows that, conflicts arising within families are mainly caused by marital infidelity and leadership struggle and could be resolved by the village heads through dialogue. Conflicts arising within or between communities are caused by leadership struggle or ownership of resources (land and water) which could be resolved by dialogue or court approach. Result also reveals that, conflicts emanate between communities and companies/government over lack of provision of infrastructures, unemployment of indigene, non-compliance to signed MoU etc. During FGD sessions, discussants admitted that, conflict do occur in the project communities and the resolution mechanism applied depends on the nature of the conflict and the capacity of the mediator(s). Most conflicts identified were resolved through dialogue and by court of law or negotiation using law enforcement agents especially Police. Family and community conflicts were best settled with dialogue and negotiation unless where serious cases like kidnapping, murder, and armed robbery cases are involved which would require the intervention of security agencies. Most conflicts are settled by imposing penalties such as fines, on the culprit, seizures of assets and ostracism.

4.12.16: Social Control Mechanisms across the Communities

During FGD sessions, social control mechanisms were critically assessed. Feedbacks received shows that, there are traditional and modern approaches to handling social tensions.

Traditionally, there are various community norms and values which each member of the community (both natives and non-natives) is expected to adhere to. Study reveals that, infidelity among women and stealing by any member of the community are considered deviant behaviours. There are penalties meted to the culprits and at worst case the person may be ostracized. Women and youths are in the forefront of enforcing these laws. Similarly, the Church and Chief priests also assist in keeping in check people's behaviours. For instance, community member (s) who steals could be threatened with invoking of curses on offenders by the juju priest. The church is also active in counselling. Deviants who are devout Christians risk being expelled from the church or congregation. Those working in palaces or other sacred places in the community may face ostracism and rejection. It was found that, offenders may lose the chance of being recommended for employment in the companies or public service. Generally, it was found that, youth and women associations, vigilante groups, the church, chief priests, communities' elders and family heads have specific roles in social control across the communities studied.

4.12.17: Natural Resources, Acquisition, Ownership and Management

Land Ownership and Land Use

As applicable in every community, land use is categorized under agricultural and non-agricultural use of land. The land use Act of 1978 stipulates that all land is held in trust to the citizens by the government. In Nigeria, and particularly the study area, the manner in which land is acquired, owned, used and transferred to successors is referred to as land tenure system. The study adopts SPDC (2019, 2017) and Akpan (2019) approach of land classification in the study area. These classes are individually-owned, family owned, community-owned and government-owned land. SPDC (2008) reported that, land could be acquired through inheritance, purchases, lease, pledge, exchange and gift (Table 4.12.19).

Table 4.12.19: Mapped Land Tenure System in the Study Area

SN	Land Ownership Classes	Principal Method of land acquisition
1.	Individual –owned	Inheritance
2.	Family-owned	Purchase
3.	Community – Owned	Exchange
4.	Government – owned	Pledge/Gift

Source: Field survey, 2018 and SPDC 2019

Result reveals that, portions of land owned by families are shared to households within the families (compounds). Occasionally, the community Head leases land to non-indigenes on request and submission of some items demanded by the community. One of the conditions for qualifying a non-indigence in this method of land acquisition is that, the person must have lived in the community for a reasonable number of years and contributed to the growth and development of the community. Discussants affirmed that, household members in distress may be allowed to lease their portion (s) of land to ease their pressing needs.

Forest and Water Resources

The communities are endowed with abundant land, forest and water resources. Aquatic resources in the area include fish obtained from the rivers and creeks, water transportation as common means of transportation from one community to another (including goods), mangrove and freshwater swamps. Forest products include timbers of various species, fuel wood, wild fruits, medical plants, snails (Plates 4.12.17), vegetables and spices. Data gathered by observation in the study area reveals that there are wide variety of wildlife including crocodiles, tigers, monkeys, birds and reptiles, etc. Members of the communities hunt the wildlife for food and other economic and social purposes. Forest land and rivers have unrestricted access except areas considered as sacred sites or places and timber which exploitation is controlled to some extent by the Forestry Department of the Bayelsa and Rivers States Ministry of Environment / Agriculture as well as right-of-way (RoW) of Oil companies. The study reveals that shrines and sacred land fall under the control of community chief priests and can only be accessed with his permission. Some studies (SPDC, 2017, Akpan 2017) reported that, by forbidding farming, housing, industrial and other forms of development in these sacred lands, the communities indirectly help to conserve the biodiversity in their various domain.

		
Fish	Forests	Snails

Plates 4.12.17: Some Water and Forest Resources in the Study area

4.12.18: Livelihood and Microeconomy

Major Economic Activities

SPDC (2019) and NDRMP (2010) reported that, the economy of the Niger Delta region is largely driven by the informal sector in terms of number of people engaged in livelihood activities. According to SPDC (2017, 2019) and Akpan (2018) the micro-economy of the Niger Delta region of Nigeria is largely dependent on natural resources. It is estimated that over 60% of the population in the region depends on natural resources in the environment for their livelihood. Fishing, farming and trading are the major occupation of the people in the study area. Deductions from FGD sessions reveal that, fishing, farming and trade in forest products accounts for over 64% of employment in the communities, but with a declining trend due to human activities. Plate 4.12.18 shows some economic activities in the study area. Over 65% of the respondents are into fishing value chain which include harvesting, drying and marketing. 20% and 10% are into farming and trading respectively while 5% are engaged in tailoring, public/civil service, construction firms and other forms of occupation in the study area. Field visit and observation in the study area revealed a large number of water bodies which makes fishing the predominant economic activity while available land is used for the cultivation of plantain, vegetables, cassava, etc. the forest resources collected by the people include bush mango, firewood, timber, bush meat, snails etc.

		
Dried fish	Vegetables and other market wares	Fresh fish

Plates 4.12.18: Scenes of microeconomic activities in the study area and major occupation

One general observation across the communities is that, households are involved in multiple economic activities as means of increasing income streams. The economic status of the communities is characterized by interaction with neighbours and people of other culture in trade anchored on local resource exploitation.

Changes in Economic Activities

Changes in Livelihood Activities

Figure 4.12.18 shows the changes in economic activities over the past few decades. Over 60% of the respondents uphold that, there are great negative changes in livelihood activities in the study area. The findings revealed a paradigm shift in livelihood activities from fishing to trading, farming and artisanry due to certain perceived impact of explorative activities in the study area. During FGD session, it was revealed that the quantity of fish caught is reducing and affecting household income.

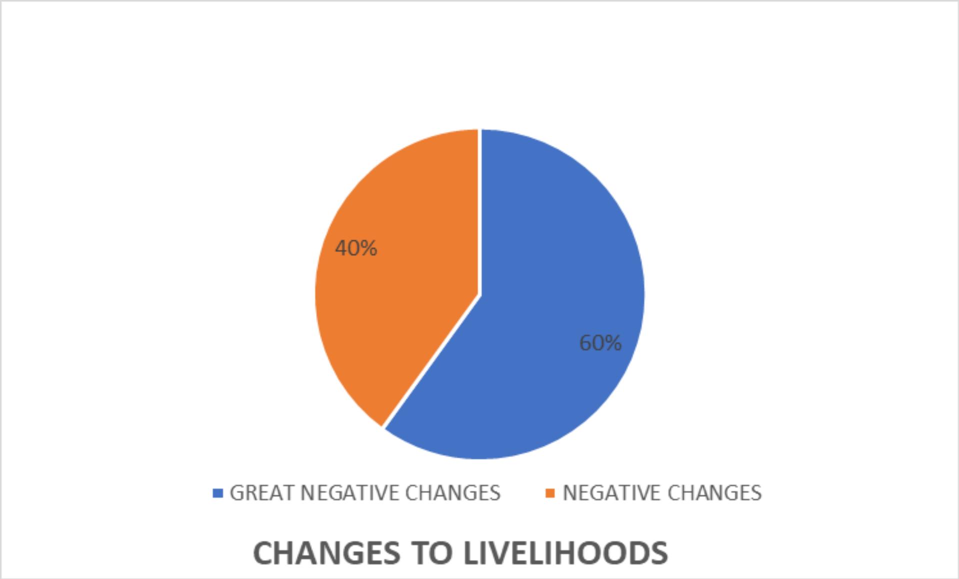


Figure 4.12.18: Changes in Livelihood Activities

4.12.19: Income Distribution

Several studies including SPDC (2019) reported that income is one of the determinants of household consumption, savings and expenditure. It is an important variable used in measuring the welfare of household members. SPDC (2011) reported that, the annual income of most households in the Niger Delta area is between N150, 000 - N 200,000.00. Present result shows that over 65% of the respondents earn between N10, 000 – N30, 000 per month from their income generating activities across the communities (Figure 4.12.19). About 25% earn between N31, 000 – N50, 000 per month while 10% earn N51, 000 and above. The result reveals that, 80% of the respondents are poor and middle-income earners in the study area. This is consistent with Akpan (2014) that greater number of rural dwellers earn very low income that is less than one Dollar a day. The result also reveals that, most households in the study area are engaged in primary activities (farming, fishing, trading etc) with a very low percentage of household members employed in secondary and tertiary sectors (oil/construction firms, public/civil service etc). UNDP (2018) and SPDC (2019) reported that income in the Niger Delta region is very low with an average income of N5,000 per month which is lower than national minimum wage. Study revealed that there is a very high-income inequality between the peasants and employees in other sectors outside of the primary (agricultural) sector. For instance, Bayelsa and Rivers states Gini coefficient (measure of income inequality) are approximately 0.48 and 0.47 respectively which is almost the same as the national figure of 0.49 (NBS, 2004). Figure 4.12.19 presents the status of households engagement in economic activities. Over 56% are in primary activity, 29% in secondary and 15% in tertiary activities.

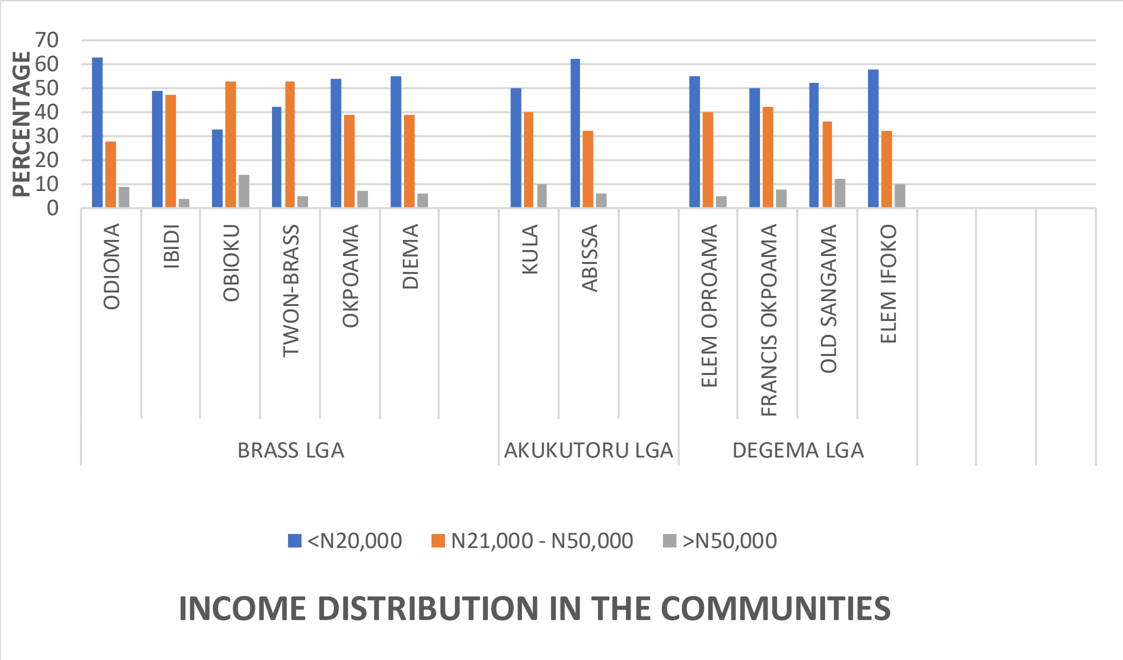
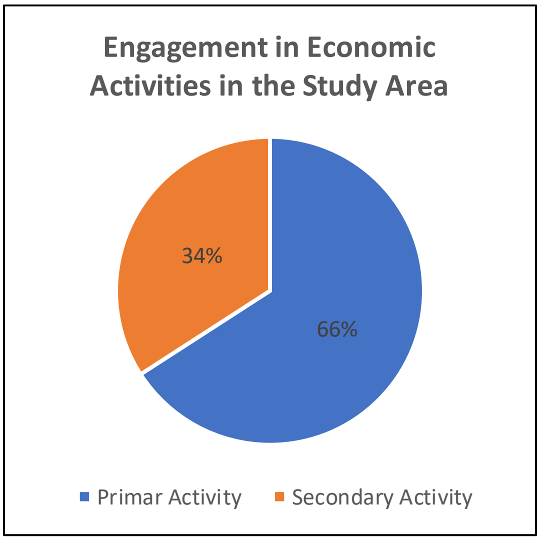
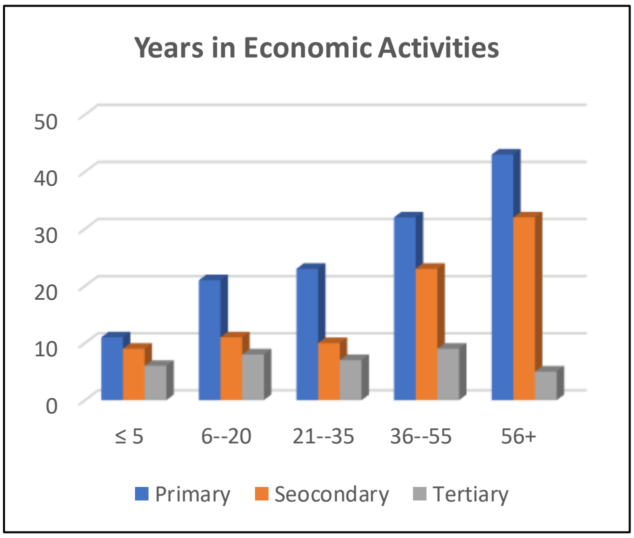


Figure 4.12.19: Income distribution in the study communities

The years of engagement of household members in economic activities is presented in figure 4.12.20. Result reveals that most respondents (67%) have spent up to 50 years on primary economic activity. Study deduced that there is increasing engagement in secondary and tertiary activities showing a gradual departure from primary activities to secondary and tertiary activities. During FGD session across the communities. The study reveals a steady increase in secondary activities across the communities in the study area. It was gathered that, development in the tertiary sector especially telecommunications and oil and gas may account for this economic shift.





Figures 4.12.20: Engagement and years in Primary Activities.

4.12.20: Human and Economic Development Indices

EMRL (2016) and SPDC (2019) reported that, indicators of human development indices are life expectancy, education, and output. Life expectancy in Delta is reported as 0.587 and Bayelsa State as 0.455. Highest Education index is reported in Akwa Ibom (0.683), followed by Rivers (0.582) and Bayelsa State (0.528). Figure 4.12.21 presents the human development and economic participation indices in the project communities. Result reveals that, across the communities, human development index is lower than the economic development index. It implies that, despite the level of economic development in the area, education, life expectancy and general output is still very indicating the need for improved social economic and infrastructural development in the area.

4.12.21: Constraints to major productive activities in the study area

According to SPDC (2019), the Niger Delta region has been facing several productive constraints since the exploration of oil activities in region. Table 4.12.21 shows the constraints faced by the communities to major production activities. During FGD session, discussants expressed deep concern on constraints to their production activities. These constraints were categorized under internal and external factors, except two factors that were cross-cutting (i.e. access to market and market infrastructures and poor road network). The internal factors identified are: low capital and knowledge/skills, inability to purchase or repair fishing gears, inadequate storage facilities, fire outbreaks in fishing settlements while external factors identified are oil potential, explorative activities by oil companies, high cost of transportation, restriction in fishing area due to facility installations, increase prices of inputs, as well as weak institutions.

Table 4.12.21: Constraints to Major Productive Activities

SN	Internal	External
1	Low capital	Oil pollution
2	Poor road network	
3	Low knowledge and skills	Sea piracy ad robbery/kidnapping
4	Fishing gears	High cost of input
5	Inadequate storage facilities/preservation methods	Restriction in fishing area boundary disputes
6	Access to market and Market infrastructures	
7	Poor records keeping and innovation	Weak social institutions
8	Fire outbreaks	

Source: Field Survey, 2018 and SPDC (2019)

4.12.22: Employment status and distribution in the study area

UNDP (2013) reported that fishing and agriculture are the two major traditional occupation of the Niger Delta people. During the colonial era, forestry was introduced as the third major economic activity in the region. It further stated that, today agriculture, fishing and forestry account for about 44% of employment but observed that all the three economic activities have declined. Figure 4.12.22 presents the employment status as well as distribution in the study area. Over 75% of the population that are unemployed depend on agriculture, fishing and forestry for their livelihood while 25% are employed in public service and oil related companies in the project communities. Findings also reveals that about 50% of the population are unskilled, 30% are semi-skilled employees while 20% are skilled. These findings are consistent with Niger Delta human development report (2013) and SPDC (2019).

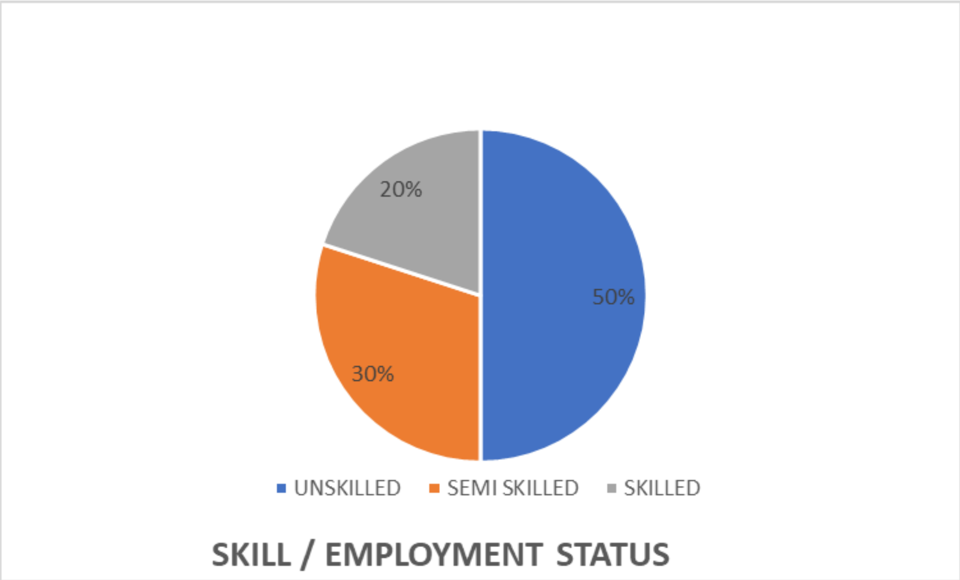


Figure 4.12.22: Employment Status

4.12.23: Household consumption and Expenditure Pattern

Many studies including Umoh, (2017), SPDC (2019) and Akpan, (2014) have linked consumption and expenditure profile as a crude measure of quality of life. The bundle of goods and services which the household can purchase is influenced by availability of funds to spend on these items. Contemporary income theory demands that an income earned is either consumed or saved (investment). Figure 4.12.23 shows that households in the study area spend higher (46%) income on food, 20% and 23% on accommodation and clothing respectively, 8% on education and healthcare, while 3% is spent on communication/utilities and items not captured here but grouped under "others". During FGD sessions in the communities, respondents expressed deep concern over increasing expenditure on healthcare, education and replacement of roof due to air pollution and acidic rainfall in the area. Result reveals that, households spent much on food items than non-food items as could be deduced from prevailing food prices in the study area (Table 4.7.11), a typical trend in underdeveloped economies.

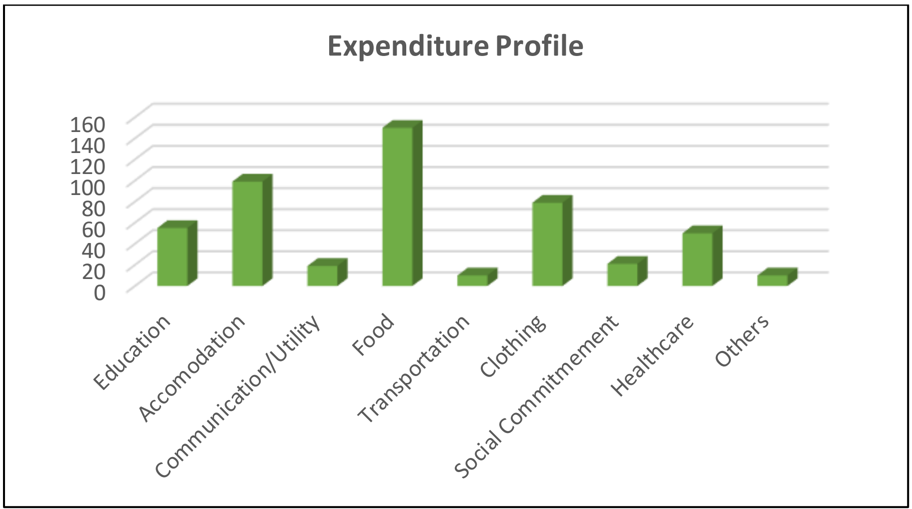


Figure 4.12.23: Household Consumption and Expenditure Pattern

Table 4.12.23: Showing prices of commodities in the study area

SN	Commodities	Prevalence Prices (Naira)
1	Crayfish	500 a bowl
2	Beans	50-80 a cup
3	Eggs	40 per Egg
4	Garri	10 cups for N100
5	Maggi Seasoning	250-300 a packet
6	Rice	80-100 a cup
7	Pepper (fresh)	200 a plate
8	Beef	300-500 per kg
9	Palm oil	150-250 a bottle
10	Groundnut oil	500 a bottle
11	Fresh fish (average size)	1500
12	Salt	100-150 per sachet
13	Fresh periwinkle	200 a cup
14	Banana	1500-2000 a bunch
15	Stock Fish	2300-2500
16	Paw-Paw/ Pineapple/Guava	200-500
17	Roasted fish (average size)	200-250
18	Skirts	500-2000
19	Wrist Watches	400-1500
20	Wrapper	2500-5000 (Nigerian Wax)
21	Rubber Slippers	250 a pair
22	Tomato	60 a tin
23	Egusi	250 per cup
24	Ogbono	400 a cup
25	Cover Shoes (open market price)	1500-2500
26	Plastic buckets (medium size)	500

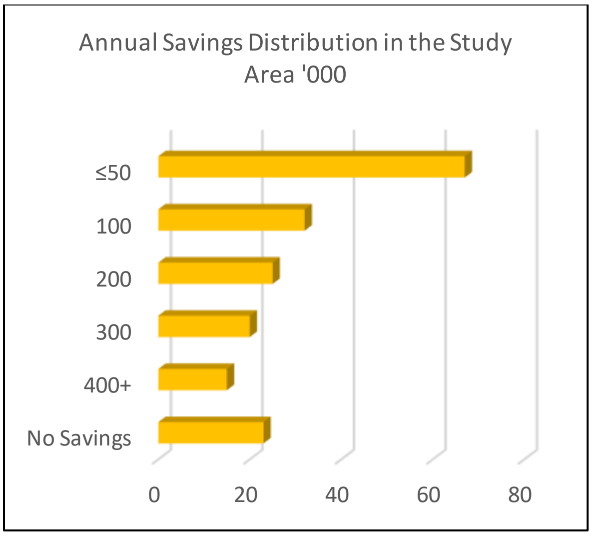
SN	Commodities	Prevalence Prices (Naira)
27	Plantain	2000-2500 a bunch

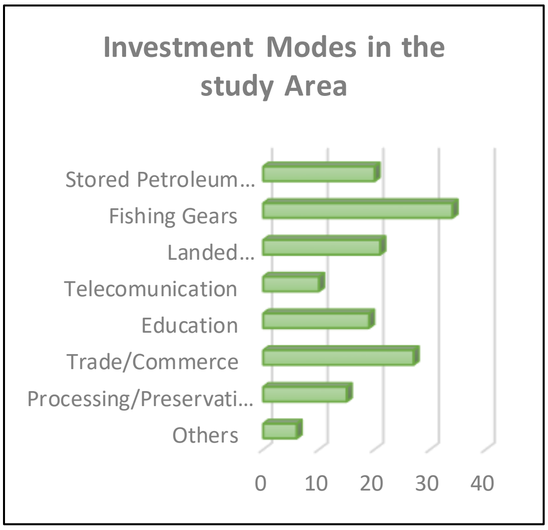
Source Field survey, 2019 and SPDC, 2019

Saving and investment patterns

SPDC (2019) and Akpan (2019) reported that, savings constitutes the basis for capital formation, investment and growth of an economy at micro and macro levels. Figure 4.7.19 shows the savings and investment patterns in the study area. The outcome of the focus group discussion sessions reveals that there are no formal savings institutions in the study area except banks and micro-finance banks located approximately 21km away from the communities, but several informal financial services providers mainly mobile money agents were identified.

Majority of the people save their money with these traditional institutions including esusu (contribution), rotatory savings and trade/credit associations. Result (Figure 4.12.24) reveals that over 20% of the population do not save at all, while 40-60% save less than N50, 000 annually. 15-20% of the population save between N100, 000 – N400, 000.00 annually. Those who imbibe the culture of savings gave reasons that, it is a safety net in times of financial distress and need. The mode of investment is linked to the type of occupation in the study area. Majority (80%) of the population prefer to invest in fishing, landed properties/houses, trade/commerce and stored petroleum products including kerosene, petrol, diesel as well as agricultural produce such as palm oil. Other critical areas of investment in study area is in education (7%), communications (9%) and mode of investment captured as “others” (5%) e.g. betnaija, pools etc.





Figures 4.12.24: Savings and Investment Patterns

Occupational Mobility and adjustment

According to Zubieta *et al.* (2015), occupational mobility refers to changes in individual occupational status. Career progression is taken as the highest driver of occupational mobility of labour. Figure 4.12.25 shows the occupational mobility status and adjustment in the study area. Findings reveal progression (mobility) of labour from the primary to secondary and tertiary sectors. FGD session especially the youth group linked this progression to advancement in technology especially in areas of telecommunications and marketing. Over 80% of the respondents affirmed that, there is flexibility and occasional movement from one occupation to another in the study area.

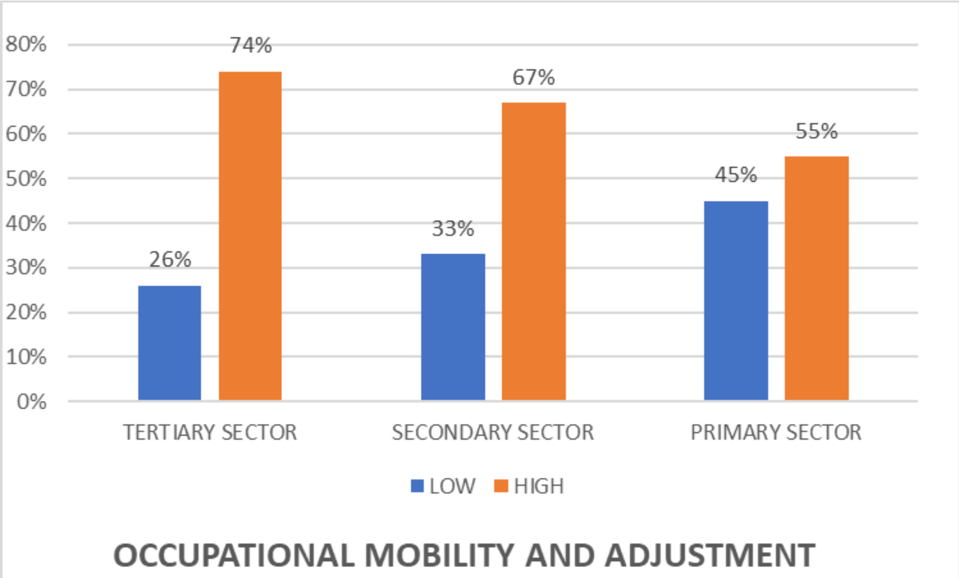


Figure 4.12.25: Occupational Mobility and Adjustment of Labour

4.12.24: Poverty profile in the study area

Danaan (2018) reported that various indicators suggest that poverty is a major obstacle to socio-economic development. Figure 4.12.26 presents the poverty status in the study area. Result reveals that 92% of the population are poor while 8% is classified as non-poor. This result is in line with Akpan (2014) which reported that, only 5% of the population control the resources in Nigeria and the Niger Delta region while 95% depends on these negligible population. This result revealed that, majority (over 70%) are relative poor as most people earn less than one dollar (N460.00) a day. The poor do not have access to affordable education, accommodation and healthcare services and lacks innovative knowledge/technical skills, infrastructure and social amenities.

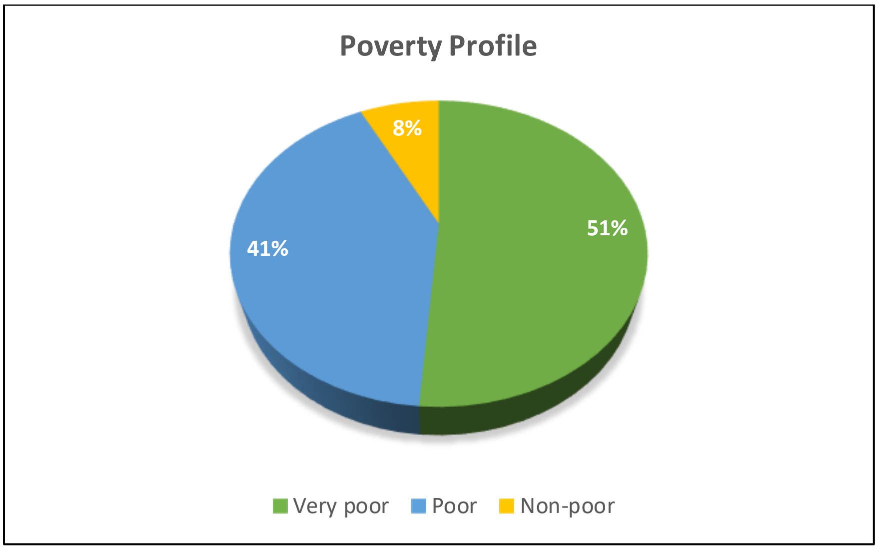


Figure 4.12.26: Poverty Status in the Study Area

Traditional market system

There are organized market days for sales of goods and services in the study area. Each of the communities maintain market days; some of the markets are actually open centers where people come to display their wares for sales on designated market days while some others are built up open sheds. The functional markets in some of the study communities were constructed by SPDC but a few are still underutilized by the communities (Plate 4.12.24).

Plate 4.12.24: A typical market in the community

Perception of respondents on trend of primary occupation

One of the contending issues raised by the communities surveyed was changes in their fishing activities. Figure 4.12.27 shows the trend on primary occupation. Three domains of assessment were deployed in this study, namely no change in quantity, decreasing quantity and increasing quantity of fish catch. Result shows that 83% of the respondents agreed that, there is huge reduction/decline in quantity of fish harvested across the fishing ports in the study area. Only 10% affirmed that, there is no change while the rest (7%) believed that there is an increase.

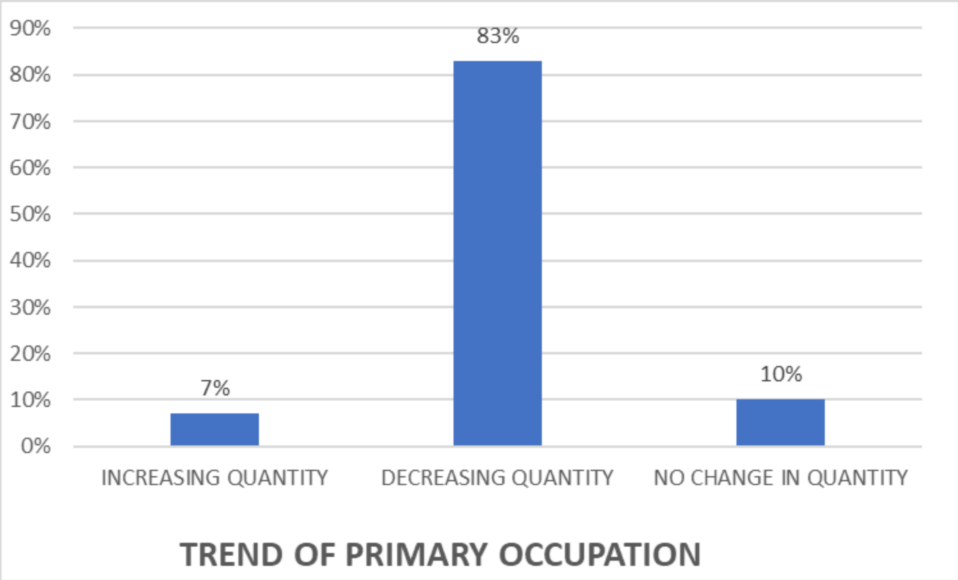


Figure 4.12.27: Trend of Primary Occupation Source: Field survey 2018

4.12.25: Infrastructural Facilities

Road Infrastructure

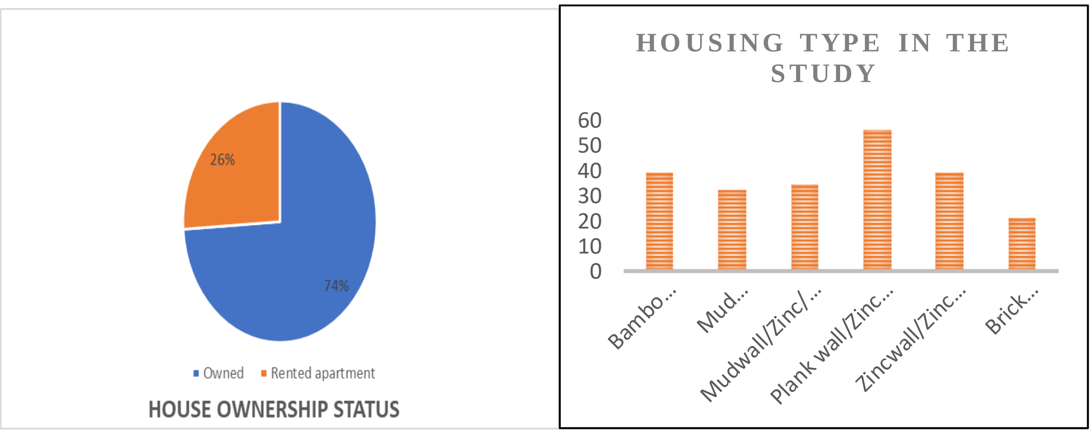
One of the critical infrastructures that could help improve the socio-economic status of a given area is good road network. During the field visit, it was observed that, there were no road networks across the study area, although Kula, Okpoama and Two-Brass seemed to be better. The major means of accessing the communities is water (Plate 4.12.25). There are feeder roads in the study area which makes it easier for residents to move from one community to the other for trade and other commercial purposes. Observation reveals that water transportation is highly accessible within the study area. About eight (8) jetties built by SPDC are functional and in use by the people.

	
Wooden bridge across swampland	Jetty to access the coastal community

Plates 4.12.25: Typical Road infrastructure in the study area

Housing Type, Pattern and Quality

According to UNDP (2018), houses in the Niger Delta region is predominantly of poor quality, especially in the swamps and creeks where many lives in mud houses with stilt and strip foundations. The housing pattern, type and structure reflect the coastal rural setting obtainable in similar communities in the Niger Delta region. Figures 4.12.29 shows the distribution of house ownership and status. About 74% of the population lives in their houses while 26% lives in rented apartments. The common types of houses in the area include those with bamboo walls and thatched roof, brick walls with zinc roof, bungalows and storey buildings. SPDC (2019) reported that, modern houses are built-in flats with cement block or brick walls and roofing such as long span corrugated aluminium sheets as well as short span Nigerian or Cameroonian sheets (Plate 4.12.26). About 48% of the population live in plank wall and mud walls with thatched and zinc roof in the study area while approximately 36% of the population live in zinc and brick walls with thatched and zinc roof and about 10% in modern bungalows and duplexes. Few households (6%) live in storey buildings with maximum of four (4) floors. This trend was similar in all the communities and is consistent with NBS (2008). The communities, however, expressed deep concern and dissatisfaction over frequent replacement of zinc roof due to acid rain and other hazardous chemical deposits emanating environmental pollution. During FGD session, most discussants complained about increasing demand for houses in the area due to increase tempo of economic and oil explorative activities in the study area. This has led to increase in cost of accommodation across the communities.



Figures 4.12.29: Housing Type and ownership distribution in the study area.

		
Storey building	Zinc/wood walls	Bungalows

Plates 4.12.30: Typical Housing structures in the study area

Possession of Household Items

According to SPDC and Akpan, (2019), household properties are categorized into two, namely: assets and liabilities. Household assets surveyed in the study communities include serviceable items such as television and radio sets, motor vehicles, motorcycles and bicycles, Engine boats, drums/Jerrycans of fuel, phones, ,chairs/tables etc, computers, cooking utensils, fishing gears, refrigerators, generating sets, non-serviceable household items (liabilities) were identified to include – unused fishing gears, unserviceable motor cars/bikes among others (Plate 4.12.31).

Plate 4.12.31: Savings and investment mainly in fishing gears, transportation and property development

Major Means of Transportation and Communication

The major telecommunications facilities are available in the study area. There are GSM base stations/mast in some of the communities especially in Kula. The common network providers in the study area are MTN, Airtel, Glo and 9-Mobile. Observation and interaction with the sampled population reveals that over 85% of the respondents owned private phones for communication purposes. Generally, it was revealed that communities still make use of town announcers/criers as local means of information dissemination in the study area.

		
Engine boats	Jetty	Motor bikes on bridge
		
Satellite Television dish	Communication masts	Jetty

Plates 4.12.32: Typical means of transportation and communication in the study area

Vehicular Volume Count (road and water), Origin and destination Survey, incidents and records of motoring Accidents

According to SPDC (2019) there is high volume of vehicular movement in the study area especially land transport, conveying goods from one place to another but over the past five to ten years, there has been increasing occurrence of road accidents in the study area. The presence of Road Safety and other security personnel especially Police and the military enhances smooth movement. Some communities that are not accessible by land experience high volume of movement of goods especially fish from the fishing settlement to another through the waterways. Speed boats are usually used for this purpose. Traffic count both on water and land is relatively high. An average of 54 persons lost their lives in the past four years due to boat mishap and 87 persons due to motor accidents in the study area (Plates 4.12.33).

	
Byke mishap	Boat mishap

Plate 4.12.34: Typical Scenes in the study area

Educational Facilities/Institutions

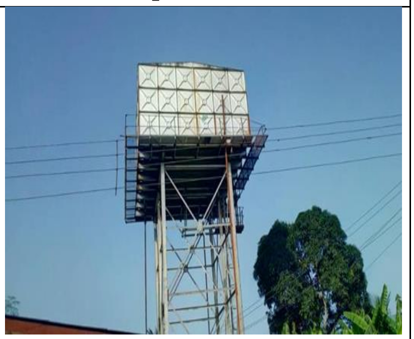
Educational institutions in the study area include government and private owned schools. Most are primary and secondary schools. Discussants during FGD sessions and during in-depth interview with key stakeholders upheld that, SPDC through her social corporate responsibility programmes have supported these communities in building and renovation of school's infrastructure such as the construction of classroom blocks and halls in Kula (Plate 4.12.35). Some schools visited have structures and teachers that can be adjudged adequate for pupils, students and teachers as well. Most tertiary institutions are accessed in the cities which are far away from the communities. Access to tertiary education is very low in the study area.

Plates 4.12.35: Educational Infrastructures and teaching/learning environment in the study area

Water supply, waste Management facilities

Water supply is inadequate in the communities. Several studies (SPDC 2019, Akpan, 2019) have linked good health to adequate water supply and sanitation. Availability of potable water in a community could go a long way to determine the state of health and quality of life of the population. Desk review and finding from FGD sessions in the study area reveals that SPDC has been the major provider of water facilities in the communities. Umoh (2017) and SPDC (2017) reported that, the defunct oil mineral production and Development Commission (OMPADEC) supplied water in Kula and other neighbouring communities. Pipe born water supply in the communities is supported by SPDC and recently by Niger Delta Development Commission (NDDC) and water from SPDC is said to have served over 80% of the population in the area (Plate 4.12.36). Observation in the communities reveals that, there are several private boreholes in the study area that complement public and donor institutions water supply in the area. Several market stores lsells bags of sachet and bottle water in the area. In addition, study revealed that 75% domestic waste generated by households in the study area were disposed in nearby bushes. Except few (25%) households deposited their waste in modern waste disposal facilities such as waste bins and polythene bags. Human waste (faeces) were deposited in water bodies using the pie toilet and open defecation systems as shown in plate interestingly, discussants agrees that, during dry season non-degradable plastic waste are burnt while decomposable waste are used as compost for farming during wet season.

		
Over hang toilet	Toilet	Waste dump
		
Water supply project	Borehole water	Pipeborne Water Project

Plates 4.12.36: Typical public water and sanitation facilities in the study area

Electricity Supply and Household Energy

Electricity supply is lacking in the communities. Electricity supply is one of the major considerations of economic growth and development in modern societies. The demand for power supply is increasing. Observation and discussion with the community members reveal that, major towns, pre-urban and some satellite communities within the proposed project area, are not connected to the national grid. SPDC, NDDC and defunct OMPADEC have played relevant roles in electricity distribution to the communities at various times. Findings from FGD sessions reveals that, SPDC and other multinationals have been supporting these communities through provision and fuelling of high-powered generators in some of the communities. Discussants affirm that, electricity supply in the communities will have positive impacts on livelihood activities especially those operating business outfits such as barbing saloon, restaurants, welding shops, entertainment centres, food preservation centres (cool rooms), tailoring shops as well as offices and other formal institutions (Plate 4.12.37).

	
Electricity supply	Electricity Project (Abandoned)
	
Fuel wood	Fuel wood

Plates 4.12.37: Energy sources in the study area

Recreational facilities and security

Availability of functional recreational facilities has a significant implication on quality of life and willingness of the people to live and remain there. SPDC (2014), Umoh and Akpan (2017) reported that, the number of functional social infrastructures has direct implications on the quality of life of citizenry. Such facilities include Civic centres, football pitches and drinking parlours, among others. Finding reveals that the larger and permanent communities within the proposed project area have more functional infrastructures than others. It was also found that most of these facilities and amenities were provided by oil and gas companies especially SPDC and her partners, although some were attributed to communal efforts. There are several private-oriented recreational facilities built and managed by the community members in addition to facilities provided by government. Several social organizations meetings are held in these centres to discuss issues beneficial to the people. Besides the community security apparatus, there are also the presence of government security personnel including the Police, Army, Navy, Customs, Civil Defence, Military Police to boost security around the communities and facilities of SPDC and other oil and gas companies both in land and water.

4.12.26: Perceptions and expectations of the communities regarding the project (s)

The relationship between the coastal communities and SPDC was described as good. The large turn-out of community members and their response during consultation and focus group discussions indicated that, the resident population is in support and acceptance of the proposed JK Explorative and Appraisals Wells project. The reactions and participation of relevant community stakeholders reveals a high understanding of several of such oil and gas projects in the area. Over 80% of the residents expressed optimism that the proposed project could bring some positive socio-economic benefits to the communities. The general disposition to the proposed project by the community members is predicated basically on the premise of positive benefits. The study critically documented the expected benefits likely to be felt from the project to include but not limited to.

- Award of scholarship which may likely give more indigenes the opportunity to go to higher institutions.
- Transportations and communication facilities and services; cargo boats, and GSM telephony facilities.
- Creation of employment to qualified indigenes of the community which have attended and completed their studies in special fields in medicine, engineering, banking, etc.
- Shoreline protection and embankment
- Provision of educational and health facilities to address the fear.
- Construction of market and soft/interest free loan to women
- Provision of basic infrastructure such as electricity, portable water, roads, recreational facilities, housing and security.
- Improved tempo of economic activities through provision of electricity and other infrastructures.
- Construction, equipping and rehabilitation of health facilities in the project area.
- Construction and renovation of classroom blocks, science and technical laboratories/workshops in schools.

- Construction and rehabilitation of landing jetties and bridges in the project communities.
- Payment of compensation to deserving communities and indigenes on natural resource exploitation
- Provision of security to indigenes to avert sea piracy which is a phenomenal threat in the project communities.
- Suppliers in the communities to be considered in procurement and contract award.
- Youth inclusion in key decision making between SPDC and the host proposed project communities.
- Youths demands the payment of FTOs directly to them.
- Construction of skills acquisition centre for the women and physically challenged persons
- Provision of preservation facilities e.g. cool rooms.

4.12.27: Anticipated Social problems and fears expressed by the communities.

Respondents expressed the following fears and likely problems from the project. These include:

- Reduction in quality and species of fishes such as croaker in the rivers.
- The Women frowned over the issue of rape and violence especially on widows and activities of sea pirates.
- The project may likely cause increase drugs intake and other substance abuse.
- Economic hardship may increase due to increase in prices as a result of influx of people.
- Increase crime rate, prostitution and cultism
- Sickness and communal problems may arise.
- Attack from unrepentant militants and kidnappers
- Water pollution from pipe laying may affect the communities' negatively.
- Aquatic animals may migrate from the community.
- Youth restiveness and teenage pregnancies are likely to occur amongst indigenous girls exposed to temptation of oil workers.
- If expectations are not implemented it might likely bring rancor due to lack of transparency.
- Reduction in number of endangered species (aquatic life)
- Reduction of life expectancy of the inhabitants,
- Possibility of oil spill and pollution is very high.

People's Expectations of the Project are:

- Creation of more employment opportunities for people in the area;
- Helping to boost the economy of the communities;
- Implementation of MoU shall accelerate the rate of development in the project communities through community development infrastructures;
- Income of land owners and families whose lands will be used for the laying of the pipelines will be enhanced (empowerment) by the project;

- More scholarships to be granted to sons and daughters of families in the communities and settlements by SPDC;
- Left over sand should be used to backfill the swamps for building and construction of concrete walkways.

4.13: Health Profile

4.13.1: Demographic characteristics of the communities

The communities and settlements are primarily rural, except for a few towns like Twon Brass in Bayelsa State and are inhabited predominantly by people of the Ijaw ethnic group, who are mainly fisher folks, traders and marine transporters. Fishing, trading, and logging are the main occupations. From literature, the age distribution structure was determined to be categorized into three structures: 0-14 years, 15-64 years, 65years and above. The data revealed that the 15-64 age group is the most populous in the study area accounting for over 60% of the entire population. This follows the same trend for communities in Rivers State and communities in Bayelsa State. See Table 3.13.1 for graphical distribution of the population trend.

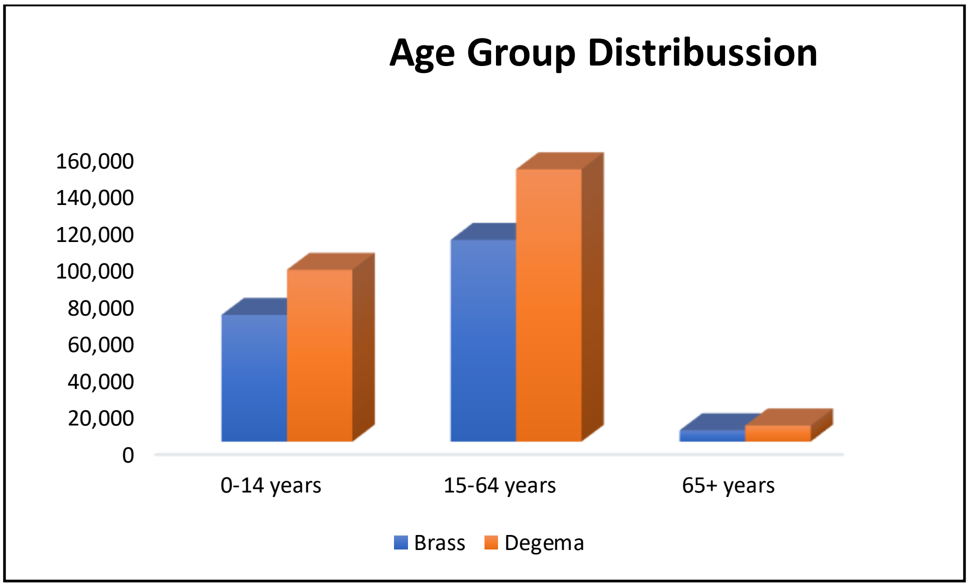


Fig. 4.13.1: Age group distribution of the host communities.

4.13.2: Birth Rates

According to the NDHS 2018 Crude Birth Rate data, it was revealed that both Rivers State and Bayelsa state have similar trends of Crude Birth Rate. However, there was no recent data to show the most recent crude birth rate at the time of this study. Notably, the focus group discussants observed there is a rapid population growth in the area. Most of the communities were initially smaller fishing settlements at the shorelines but have now evolved into much larger communities. Substantial increase in births have been alluded to by members of the communities, but there are no accurate records to confirm the claim since no orthodox health care institutions exist in the area. Figure 4.13.2 reveals the population is increasing rapidly. The community residents also mentioned that this could be due to increaring cases of teenage pregnancies.

4.13.3: Mortality Pattern

The mortality pattern in the communities was determined using the Crude Death Rate (CDR) and Maternal Mortality Ratios (MMR).

Crude Death Rate (CDR)

The leading causes of deaths in the communities are communicable and non-communicable diseases. Chief among them are malaria, acute respiratory tract infections, measles, gastroenteritis and neonatal tetanus in the children category and non-communicable diseases like hypertension, stroke, diabetes mellitus, liver diseases, arthritis, and cancer in the adult group. From focus group discussions, deaths were said to be common among the children and women during childbirth. From the estimates, an average of 11.6 deaths per 1,000 population occurred in the communities in one year. These figures are slightly lower than the National average of 12.5 per 1,000 persons per annum. (World Bank, 2017).

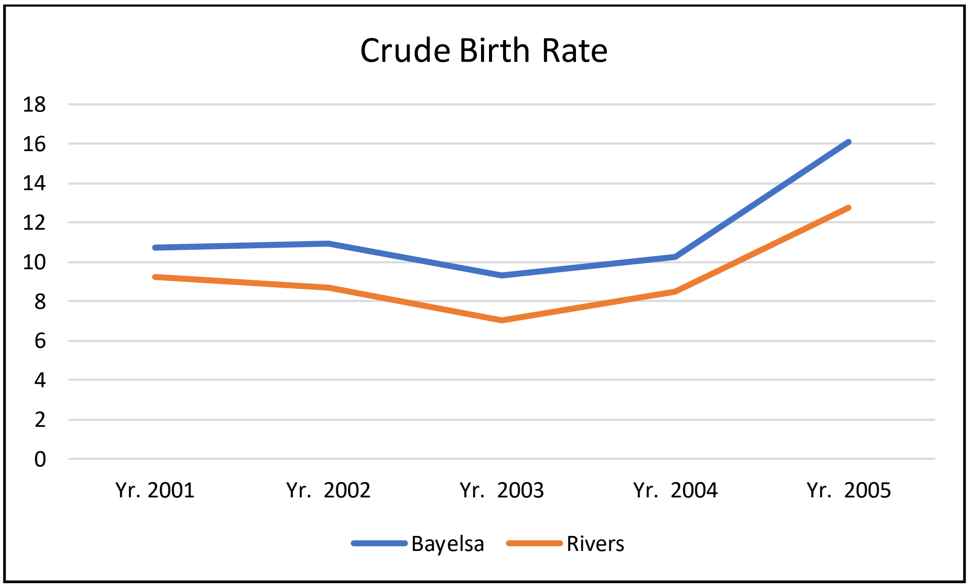


Fig. 4.13.2: Crude Birth rate for the Host Communities by States

Maternal Mortality Rate (MMR)

Maternal mortality is the death of a woman during pregnancy, delivery or from puerperal conditions or death within 42 days of termination of pregnancy. Information derived from women during focus discussions (FGDs) appears to suggest that maternal mortality was common in the area. Discussants indicate that at least 23 women have lost their lives in the circumstance in the past four years. The discussants attributed the problem to the absence of health care facilities in the area and the cultural practice of birth attendance by Traditional Birth Attendants (TBAs). The TBAs are only helpful in cases of uncomplicated deliveries. In the event of complications related to the direct maternal deaths during delivery, they are entirely helpless. This is because most maternal deaths often arise from haemorrhage, obstructed labour, eclampsia, septicaemia and septic abortions (WHO, 2014a).

4.13.4: Healthcare Facilities and Services

Orthodox health care facilities and services are not existent in most of the project area. Discussants recall that existing ones were torched during various communal crises. The people depend mainly on poorly equipped patent medicine stores with limited variety and quantity of essential drugs, traditional medicine practitioners and traditional birth attendants. Severely sick persons are ferried to the Abonnema and Degema General Hospitals, or to communities with health centres, like Kula, Elem Sangama and Soku all of which are far from most JK stakeholder communities. The practice of traditional medicine in the area consists of the use of herbs, home-prepared alcoholic concoctions, remedies made from a mixture of leaves or fruits and scarification marks on the skin. Commonly used traditional remedies include pawpaw leaves (*Carica papaya)* for treatment of malaria, alligator pepper (*Afromomum melegueta)* for sore throat and lemon-orange *(Citrus aurantium)* for abdominal upsets. Other commonly used herbal remedies are listed in Table 4.13.4.

Table 4.13.4: Commonly Used Medicinal Plants

Medicinal Plant Local Name	**Use**
Igira	Diabetes
Epe	Malaria
Dogon yaro	Malaria
Idata	Scabies
Uchichi	Healing wounds
Okpubulu	Hernia
Unuru, agala	Eye problems
Ogbuchuru	Healing wounds
Ugbola	Malaria
Ukwoline	Eye
Udo	Hernia
Bitter leaf	Diabetes
Uche, ubulu	Malaria
Enyi	Hernia
Ewe madu	Malaria
Ubulu	Stomach ache/pains
Nsikala, Enyi	Stomach ache
Ikite	Blood clot

Source: SPDC Field Studies Sept 2015

4.13.5: Disease Pattern and Prevalence

Common diseases in both the Rivers and the Bayelsa host communities axis of the project area based on information from Focus Group Discussions and Key Informant interviews include malaria, febrile convulsions, respiratory tract infections, diarrhoea, skin lesions, worm infestations, measles, and neonatal tetanus among the children. Malaria, hypertension, stroke, diabetes mellitus, arthritis, pregnancy-related complications, chronic liver disease, tuberculosis, asthma and chronic respiratory tract infections, eye problems, inguinoscrotal hernia, peptic ulcer, injuries, burns, and toothaches, etc, are prevalent among the adult population. In both the adult and childhood populations, malaria emerged as the highest cause of morbidity in the community. The discussants expressed their desire to own and use Long Lasting Insecticidal Nets to enable them prevent malaria. Proxy data from the Multiple Indicator Cluster Survey (MICS) (2017) mirrors the morbidity characteristics of children under five years in the project area (Figure 4.13.5).

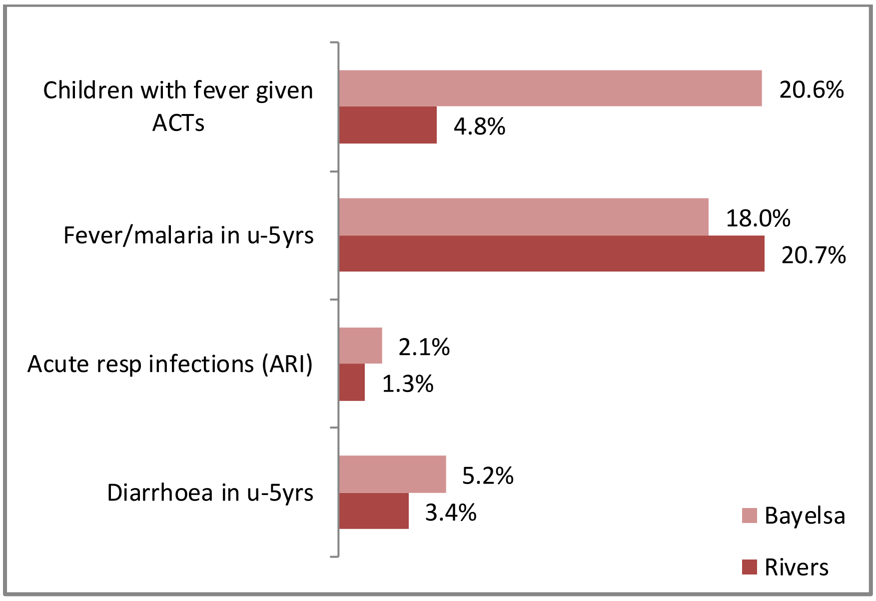


Figure 4.13.5a: Morbidity pattern of the children under 5 years

Malaria, diarrhoea and acute respiratory tract infections remain the most important causes of ill-health and deaths among children in Nigeria. Nigeria experiences an estimated 100 million malaria cases with over 300,000 deaths per year, with most of these deaths occurring in children (WHO, 2015a). The Nigerian government introduced the National Malaria Elimination Programme initiative to eliminate the disease. Some of the recommended strategies are the use of insecticide-treated bed nets (ITNs) by households, especially children under five years and pregnant women and early or timely home treatment with artemisinin combination therapy (ACTs). Unfortunately, however, these recommendations are largely not adhered to. Several reasons have been given for the non-adherence, which include the high cost of the ACTs (Pulford *et al*., 2011). Table 4.13.5 shows the total health facility attendance versus out-patient clinic attendance versus total confirmed malaria cases in Brass and Degema LGAs. Both LGAs show a similar proportion of about a sixth of out-patient clinic attendees being confirmed malaria positive.

In the project area, diarrhoea was estimated to occur in between 1.5-2.5% of the children under five years. The poor water supply situation is a possible contributor to the wide incidence of diarrhoea in the area, although the estimated prevalence rate markedly lower than the national prevalence of 18.8 percent (NBS/UNICEF, 2017).

Acute respiratory tract infections (ARIs) were also estimated to occur in 1.3-2.5% of the children in the project area. ARIs constitute the major causes of mortality and morbidity among under-five children of the developing world. (Ajobiewe *et al*., 2018). Air pollution is a risk factor for the disease complex that has been severally implicated in its emergence. Therefore, indoor air pollution from regular use of firewood in the communities and outdoor pollution by uncontrolled gas flaring in the Niger Delta are of major concern.

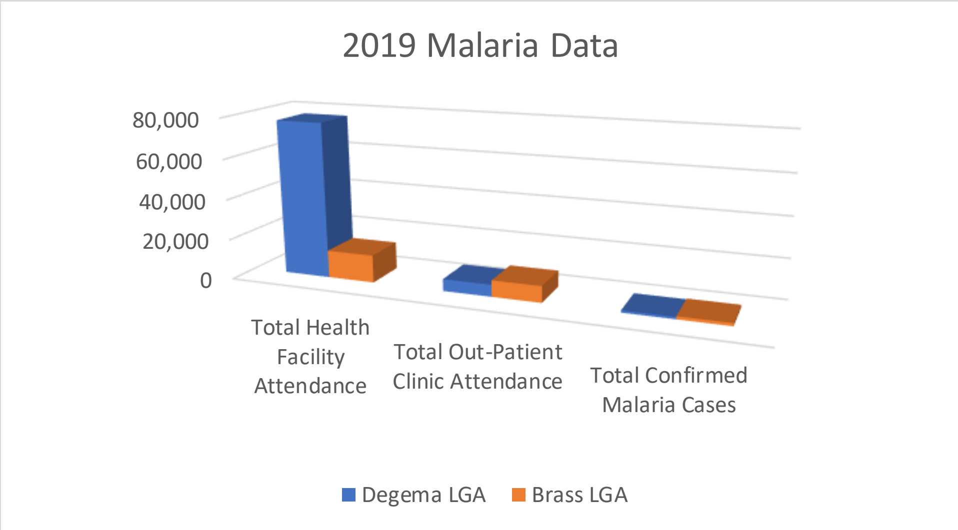


Figure 4.13.5b: 2019 Malaria Data in Brass and Degema LGAs

Source: DHIS2

4.13.6: Assessment of Blood Pressure of Adults

A total of 81.2 % of the men and 83.6% of the women in the Rivers State axis of the project area had normal blood pressure values, while 78.4% of the males and 81.9% of the females had normal blood pressure values in the Bayelsa axis (Figure 4.13.6). However, 18.8% of men and 16.4% of the women had elevated blood pressures in the Rivers axis, and 21.6% of the men and 18.1% of the women also had elevated blood pressures in the Bayelsa axis. The prevalence of hypertension was similar to what has been reported in many parts of Nigeria, which is in the range of between 10% and 20% (Akintunde, 2009). Hypertension is a known risk factor for several chronic morbidities which include kidney failure, cardiovascular diseases and stroke (WHO, 2015a).

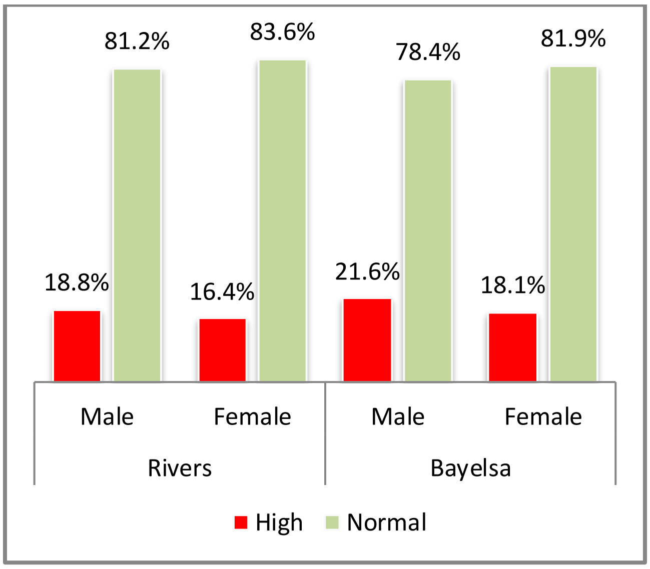


Figure 4.13.6: Prevalence of hypertension in the area

4.13.7: Women's Reproductive Health

The use of any form of modern contraceptives is very limited in the proposed project area. From estimates acquired, about 6.7% of the women in the Bayelsa communities and 8.8% in the Rivers communities had access to modern contraceptives. Part of the reasons for non-use includes the absence of health care services in the area and the notion that children come from God and any attempt to subvert the will of God might attract his wrath. It is important to emphasize that antenatal care is part of health promotion, disease prevention, early detection and treatment of complications, birth preparedness and complication readiness for women.

Concerning delivery by skilled attendants, an estimated 12.3% in the Bayelsa axis and 17.0% in the Rivers axis had their childbirth attended to by qualified health care providers. Skilled care during and after childbirth saves the lives of several women and newborn babies. The absence of health care services and the cultural preference of traditional birth attendants in the area is a considerable challenge to the conventional health system.

4.13.8: Childhood Immunization

Immunization services in the project area are only carried out as outreach services from the catchment health care facilities and during the National Immunization days or the Maternal, Newborn, Child Health Weeks that are carried out biennially each year, in May and November. Although no reliable records exist, some women attest their children have some immunization, but cannot confirm if they are fully immunized or not. Certain childhood deaths in the communities were attributed to lack of adequate immunization. According to the World Health Organization, immunization prevents an estimated 2 to 3 million deaths of children every year (WHO, 2015b).

4.13.9: Nutritional Assessment and Household Food Security

The project area shares similar dietary staples with other parts of the Niger Delta. The diet consists of a mixture of more fish proteins, carbohydrates, fat, vitamin, fruits and water.

However, food items are more expensive in the area because of its remoteness and the high cost of transportation. The practice of breastfeeding is good and well-received. Most children in the project area were noted to have normal weight-for-age and height-for-age.

4.13.10: Social and Lifestyle Issues Affecting Health

Discussants estimate that about 15% of adult males smoke cigarettes while a lesser proportion smoke the *Indian hemp*. In the same vein, nearly half of the adult populace indulge in various degrees of alcoholic use. However, the use of condoms to prevent sexually transmitted infections is said to be very low among community members. There was no evidence of commercial sex workers from the accounts given.

HIV/AIDS and other Sexually Transmissible Infections

Nearly all discussants in the area are aware of the infection called HIV, and some attested to the fact that they knew someone infected with it. However, individuals with comprehensive knowledge of the virus are few. Most of them can mention only one or at most two of the conditions. People are said to have a comprehensive knowledge of HIV/AIDS when they have: (1) Knowledge that the use of condoms and having sex with only one faithful HIV negative partner is protective against HIV (2) Knowledge that appearance has nothing to do with HIV infection and (3) Rejecting at least the two most common local misconceptions or myths about HIV transmission, like mosquito bites or witchcraft can transmit HIV infection. (Sahile, Mekuria & Yared, 2015). These findings buttress the fact that a lot more sensitization campaigns are needed in rural and remote communities. Although emerging information has supported the fact that HIV/AIDS is on the decline in Nigeria, there is still much disparity in prevalence rates. Moreover, the Niger Delta region now bears the burden of the infection (NAIIS, 2019).

4.13.11: Environmental Health

The effect of the environment on human health is very significant for human existence. The World Health Organization (WHO) estimated that about thirteen million deaths occur annually from preventable environmental causes (WHO, 2009). The survey, therefore, assessed the environmental health characteristics of the host communities by the availability of potable water; its quantity, quality, and access; solid waste management; sewage and sullage disposal methods; cooking practices; insect vector prevalence and pest and control mechanisms. It also looked at environmental noise levels and air quality.

Water Supply

The available sources of water supply to the host communities are hand-dug (shallow) wells, rainwater, commercialized water (in sachets) popularly referred to in Nigeria as "pure water". It was recorded during the discussion that respondents from Amakiri Komboko in Olo Sangama community admitted to the availability of borehole in their community. However, other communities indicated shallow wells as their source of water supply. (Table 4.13.11). This shows that there is potable water in the area. The occurrence of diarrhoeal diseases in the area is reportedly high.

Table 4.13.11: Sources of Domestic water in the communities

Community	Water scheme	Borehole	Shallow well	Commercial water (water sachet)	Rainwater
Rivers State communities					
Ibidi	✗	✗	✓	✓	✓
Kulakiri	✗	✗	✓	✓	✓
Theophiluskiri	✗	✗	✓	✓	✓
Elem Oproama	✗	✗	✓	✓	✓
Francis Okpoama	✗	✗	✓	✓	✓
Elem Ifoko	✗	✗	✓	✓	✓
Amakiri Komboko	✗	✓	✓	✓	✓

✗Not available ✓Available

Source: Fieldwork

Solid Waste Disposal

There is no organized system of solid waste collection and disposal in the area. Most wastes are dumped in the open and along the shorelines. This poor environmental practice can play a role in the blockage of the natural drains/natural water flow channels, thereby causing flooding, which most of the communities complained about. It may cause many adverse health effects because disease vectors and vermins like houseflies, cockroaches and rats are attracted to refuse. Solid wastes can also contaminate shallow water wells that are the primary source of domestic water supply in all of the communities. Overall, it is estimated that approximately 75% of the households collect and dump their solid wastes on the river banks, 20% dump theirs openly in the communities, while 5% burn their wastes (Figure 4.13.11).

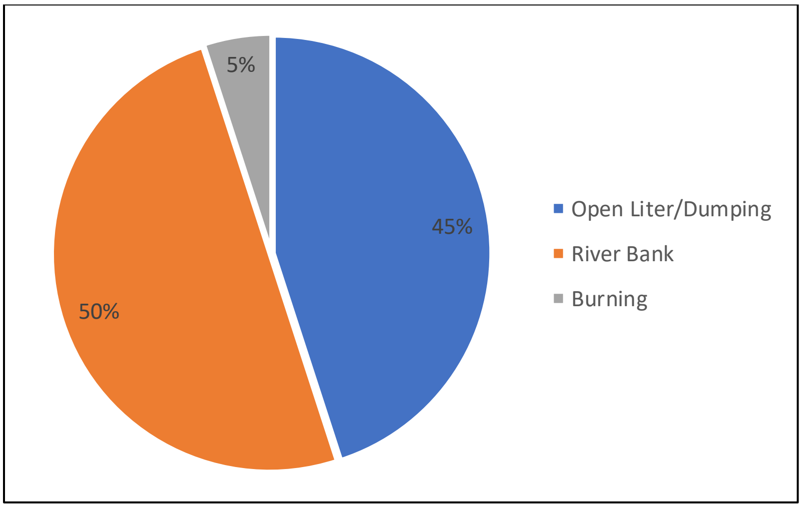


Figure 4.13.11: Sources of refuse disposal in the communities

Sewage and Sullage Disposal

Sewage disposal in the communities of the JK project area is through the jetty toilet system (Figure 4.13.12). This system is characterized by the open discharge of human waste into the rivers and creeks. Not only is it unsightly, but it is also unsanitary, and exuding of offensive odours. These toilets are mainly communally owned and shared. They provide a veritable source of infection in the community, especially among children with poor handwashing practices. Flies, cockroaches and over diseases vectors transfer bacteria and viruses from human wastes to the human diet and other edible products, causing diarrhoea, poliomyelitis, gastroenteritis, etc, which have been implicated in the spread of diarrhoeal diseases, a common killer of children in Nigeria (UNICEF, 2008; WHO, 2011a). This type of toilet system is widespread in all riverine communities in the Niger Delta and is culturally usual in centuries. However, with improvements in knowledge among the people, a more modern and sanitary toilet system is preferable and desirable, but the high water table limits this in the area.

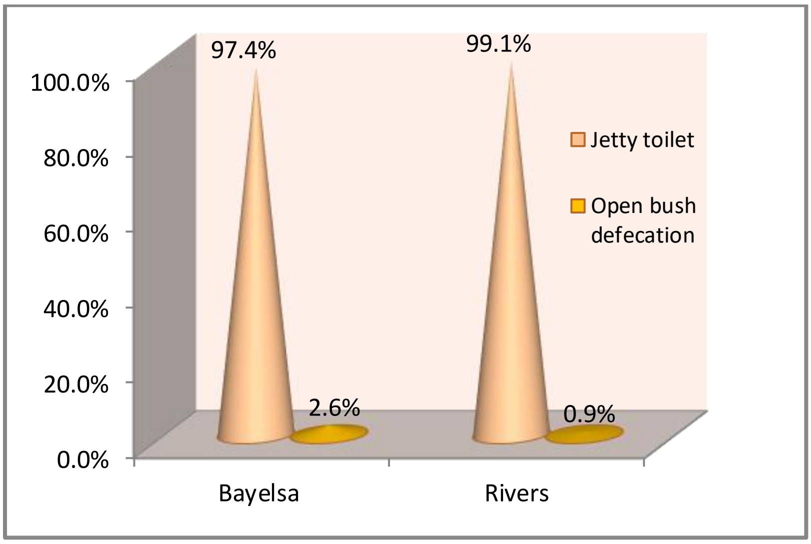


Figure 4.13.12: Sources of sewage disposal in the communities

Cooking Practices

According to the focus group discussants, majority of residents in the community are exposed hazardous air pollutants since household cooking is done by the use of adulterated kerosene, firewood, and charcoal. The firewood is sourced locally from the mangrove forest that is abundant in the area, while the kerosene is sourced mainly from illegal ‘artisanal' refiners of stolen crude oil. The depletion of the mangrove for firewood is a significant factor in environmental degradation. Moreover, the locally refined kerosene is popularly called "*Kpo-fire”* because of its high flammability which is known to have caused several fire disasters and loss of lives and properties in the Niger Delta region as a whole. Nevertheless, many people continue to use it because of the scarcity of good quality kerosene in the market and the fact that it is cheaper. Several health risks and hazards are associated with the use of firewood as cooking fuel in homes. Firewood burned indoors, produces toxic fumes that threaten health of inhabitants. According to the World Health Organization, smoke from indoor fires kills over 1.6 million people in developing countries every year (WHO, 2014b).

Air Quality

The area, like most others in the Niger Delta, has suffered significantly from air pollution arising from oil and gas exploration activities, especially from artisanal refineries as admitted by the discussants. Residents have complained of repeated respiratory tract diseases, especially among the children and very elderly persons, which they believe are associated with the poor air quality in the area. Although these claims could not be substantiated because of lack of health care facilities in his area. Chronic exposure to air pollution is responsible for the exacerbation of asthmatic attacks, cardiac failure and chronic bronchitis and Chronic Obstructive Pulmonary Disease in adults while children are prone to wheezing and difficulty in breathing, leading to increased mortality (Ana, Sridhar, and Bamgboye, 2009). Air quality measurements of the area are aptly captured in the biophysical section of this report.

Noise levels

Noise levels in the communities often arise from engine boats and helicopter flights. Otherwise, most places in the area are near pristine by noise levels. Details of the noise level measurements are presented in the biophysical section.

4.13.12: Communities' Perception of the Proposed Project Benefits

The people view the proposed project as beneficial, and a catalyst for development in their communities. They believe that the project will bring about some infrastructural developments in the area such as electricity, water projects, health care services, erosion control initiatives, etc. They also believe that the project will provide new jobs and skills training for them.

Communities' Perception

- They do not anticipate any adverse effects of the project, except a few, bordering on oil spills which may contaminate their river and affect their fishing business.
- They were concerned that oil spills can also cause them economic losses if their fishing gears come in contact with oil because the gears become damaged in the process and will require replacement.

Communities' Expectations from SPDC

The people's expectations were in the area of:

- New business opportunities for jobs.
- Provision of potable water and health care services.
- Essential amenities like rural electricity to promote income-generating activities that will impact on the local economy of the area.
- Provision of skills-based training and soft business loans to stimulate business growth in the area.
- The provision of scholarships for their children for secondary school and university level education.

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 endeavoured 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, 2018;
- 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: Associated and Potential Impacts of the JK Exploration and Appraisal Wells Project

Project Phase	Project Activity	Potential and Associated Impacts
PREMOBILIZATION	Survey Consultation	• Risk of accident from vessel collision • Risk of Piracy & kidnapping
MOBILIZATION	Mobilization (equipment and personnel), and Rig Movement	• Impairment of air quality • Increase in noise and vibration • Risk of accident • Risk of Piracy and kidnapping • Aggregation of bottom sediment
CONSTRUCTION	Site preparation (piling)	• Increase in noise and vibration • Fish-kills during piling activity • Risk of accident from dropped objects and structural failures • Impairment of water quality (turbidity and suspended solids)
	Installation and positioning of Wellhead Platform	• Increase in noise and vibration • Interference with fishing activities • Risk of accident from lifting and hoisting activities • Risk of Piracy and kidnapping • Impacts of Wastes (metal scrap)
	Drilling	• Impairment of air quality • Noise and vibration nuisance • Injuries and death from failure of BOP and explosion • Impairment of water and sediment quality from accidental release of hydrocarbons, drill cuttings • Increased waste volumes - drilling cuttings and muds • Smothering of benthic flora and fauna • Interference with marine wildlife

Project Phase	Project Activity	Potential and Associated Impacts
		• Accidents and injuries from anchor and mooring failures, crane accidents, machinery/propulsion failure • Accidental ignition of released hydrocarbons • Structural failures due to fatigue – Derrick collapse, crane collapse • Risk of dropped objects during lifting and hoisting activities
DEMOBILIZATION	Demobilization of rig, equipment and personnel	• Impairment of air quality • Water traffic incidents • Improper disposal of materials removed from site • Increase in noise and vibration level • Loss of employment/ income • Risk of accident from vessel collision • Risk of Piracy & kidnapping
COMMISSIONING	Commissioning	• Increase in Business opportunities • Air quality impairment from Well flare/vent • Risk of Piracy & kidnapping • Influx of Commercial Sex Workers
OPERATIONS AND MAINTENANCE	Operations and Maintenance	• Improper disposal of materials removed from site • Equipment failure and damage leading to injuries/fatality • Air quality impairment from Well flare/vent • Risk of Piracy & kidnapping • Leaks from process pipes, Well head equipment and flanges

Project Phase	Project Activity	Potential and Associated Impacts
DECOMMISSIONING & ABANDONMENT	Removal of surface installations Plugging of wells Site restoration	• Increase in noise and vibration • Impairment of air quality from emission of HWR • Risk of Piracy & kidnapping • Increase potential for water traffic accidents/ injury • Potential for conflicts arising from labour issues • Injury/fatalities in workforce • Impairment of surface water and sediment quality from complete decommissioning activities

5.5: 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.

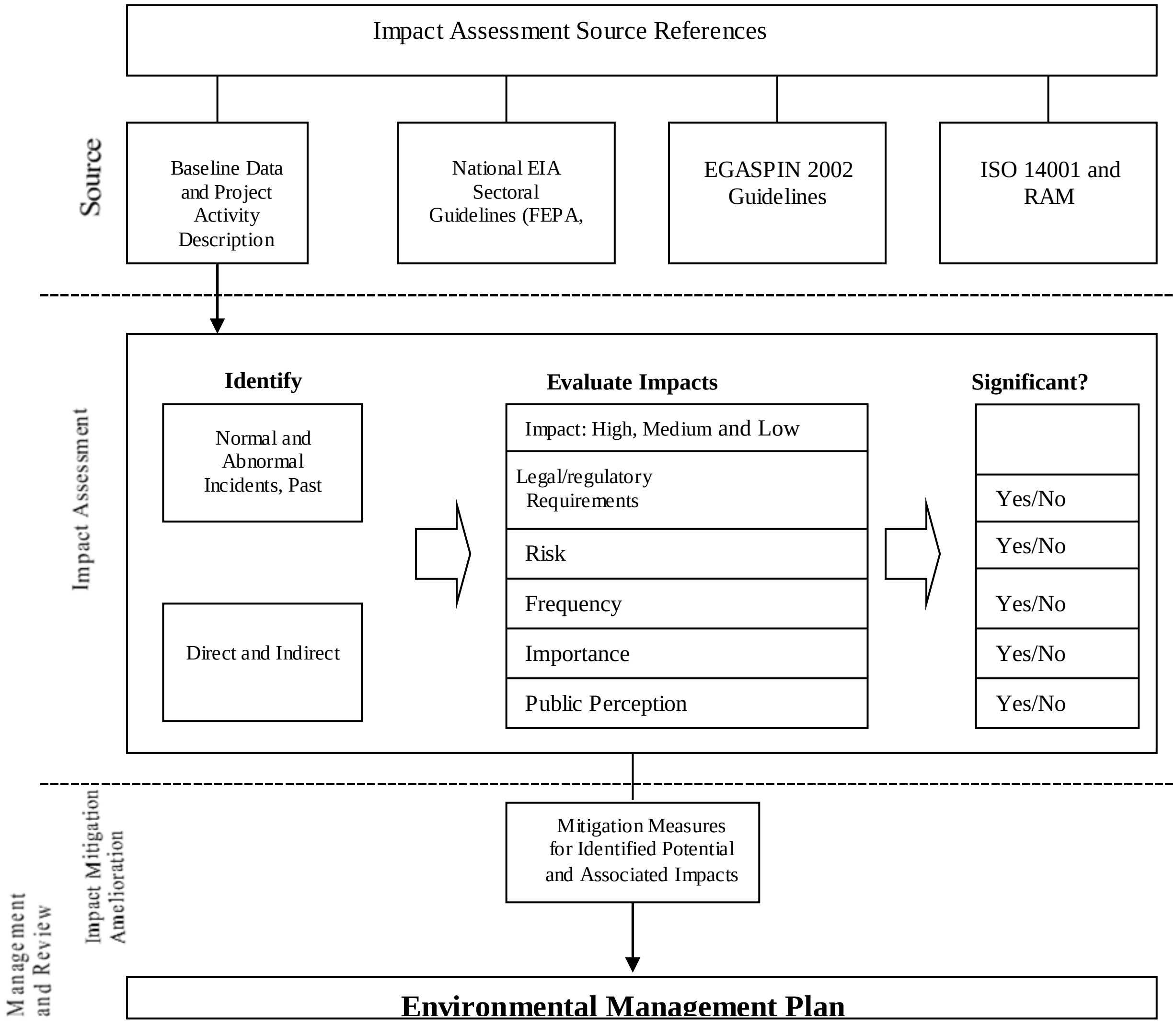


Fig. 5.1: Approach to Impact Assessment

5.6: 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 5.2 and Table 5.3.

Table 5.2: Risk Assessment Matrix

Risk Assessment Matrix

SEVERITY	CONSEQUENCES				INCREASING LIKELIHOOD				
	People	Asset	Community	Environment	A Never heard of in the *Industry	B Heard of in the Industry	C Has happened in the *Organization or more than once per year in the Industry	D Has happened at the *Location or more than once per year in our Organization	E Has happened more than once per year at the Location
0	No injury or health effect	No damage	No effect	No Effect					
1	Slight injury or health effect	Slight damage	Slight effect	Slight Effect					
2	Minor injury or health effect	Minor damage	Minor effect	Minor Effect					
3	Major injury or health effect	Moderate damage	Moderate effect	Moderate Effect					
4	*PTD or up to 3 fatalities	Major damage	Major effect	Major Effect					
5	More than 3 fatalities	Massive damage	Massive effect	Massive Effect					

*PTD- Permanent Total Disability
*Industry: Upstream Oil & Gas industry (includes UPO; UPD, Integrated Gas).
Afam Power Plant to ref. Gas and Power industry
*Organization: Upstream Nigeria (SCiN)

Location:
- Cluster of offices e.g. IA, RA & Lagos office complex (BOI & Freeman House together)
- BOGT, FoT, Bonga, EA respectively
- District (or Facilities) under one PUM e.g PH1, PH2, Afam V1, Soku, Land 1-West, Land 2-East respectively
- Drilling rig under a DSV
- Suite of project sites under a Project Manager
- Seismic party (under a party manager); Geomatics
- Pipeline land & swamp respectively (East & West combined)
- SNG, SNCPFA respectively
- Vehicle pools (PHC, Lagos etc. respectively)

SE Systems & Assurance: UPO/G/SY

Table 5.3: 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
3	Localized effect	Limited loss of discharges of known toxicity. Repeated exceedance of statutory or prescribed limit.
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)

5.7: 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 5.4. The potential and associated impacts of the project are presented in Table 5.5.

Table 5.4: Impact Value and Rating

<table>
<tr><th>Impact value</th><th>Cut off values</th><th>Impact Rating</th></tr>
<tr><td>L+R+F+I+P</td><td><8</td><td>Low</td></tr>
<tr><td>L+R+F+I+P</td><td>≥8 but <15</td><td>Medium</td></tr>
<tr><td>L+R+F+I+P</td><td>≥15</td><td rowspan="3">High</td></tr>
<tr><td>F + I</td><td>≥6</td></tr>
<tr><td>P</td><td>= 5</td></tr>
<tr><td colspan="2">Positive</td><td>Positive</td></tr>
</table>

Table 5.5: Ranking of Potential and Associated Impacts of the JK Exploration and Appraisal Wells Project

Project phase/Activity	Impacts	Impact Description				Impact Qualification				Impact Quantification							Impact Rating
		Positive	Negative	Direct	Indirect	Short term	Long term	Reversible	Irreversible	L	R	F	I	P	Total	F+I	
Premobilization - Consultation Survey	Risk of accident from vessel collision,		√	√		√	√	√	√	0	3	3	3	3	12	6	H
	Risk of Piracy & kidnapping		√	√		√	√	√	√	0	5	3	5	5	18	8	H
Mobilization Equipment & personnel Rig Movement	Impairment of air quality from equipment		√	√		√		√		3	1	3	1	1	9	4	M
	Increase in noise and vibration		√	√		√		√		3	1	1	3	1	9	4	M
	Interference with fishing activities		√	√		√		√		0	1	1	3	1	6	4	L
	Interference with water transport		√	√		√		√		0	1	3	1	1	6	4	L
	Risk of accident from marine collision		√	√		√	√	√	√	0	3	3	3	3	12	6	H
	Risk of Piracy & kidnapping		√	√		√	√	√	√	0	5	3	5	5	18	8	H
Site preparation (piling)	Increase in noise and vibration from heavy machineries		√	√		√	√	√		5	3	3	3	1	15	6	H
	Interference with fishing activities		√	√		√		√		0	1	1	3	1	7	4	L
	Risk of accident from dropped objects and structural failures		√	√		√	√	√	√	0	3	3	3	3	12	6	H
	Risk of Piracy & kidnapping		√	√		√	√	√	√	0	5	3	5	5	18	8	H

Project phase/Activity	Impacts	Impact Description				Impact Qualification				Impact Quantification							Impact Rating
		Positive	Negative	Direct	Indirect	Short term	Long term	Reversible	Irreversible	L	R	F	I	P	Total	F+I	
	Fish-kills		√	√			√		√	0	3	3	3	1	10	6	H
	Aggregation of bottom sediments		√	√			√		√	0	3	3	3	1	10	6	H
	Impairment of water quality (turbidity and suspended solids)		√	√			√		√	0	3	3	3	1	10	6	H
Installation and positioning of Wellhead Platform	Increase in noise and vibration		√	√		√	√	√	√	3	3	3	3	1	15	6	H
	Interference with fishing activities		√	√		√		√		0	1	3	3	1	8	6	M
	Risk of accident from lifting and hoisting activities		√	√		√	√	√	√	0	3	3	3	3	12	6	H
	Risk of Piracy & kidnapping		√	√		√	√	√	√	0	5	3	5	5	18	8	H
	Impacts of Wastes (metal scrap)		√	√		√		√		3	1	3	3	3	13	6	H
	Impairment of air quality from emissions		√	√		√		√		3	1	1	1	1	7	2	L
	Duty of care extended to Contractor yard	√		√		√	√	√		-	-	-	-	-	-	-	P
Drilling Well testing	Impairment of air quality		√	√		√		√		3	1	3	1	1	9	4	M
	Noise and vibration nuisance		√	√		√		√		3	1	3	1	3	11	4	M
	Injuries and death from failure of BOP		√	√		√	√	√	√	0	5	1	5	5	16	6	H

Project phase/Activity	Impacts	Impact Description				Impact Qualification				Impact Quantification							Impact Rating
		Positive	Negative	Direct	Indirect	Short term	Long term	Reversible	Irreversible	L	R	F	I	P	Total	F+I	
	Explosion from Well blowout		√	√		√	√	√	√	0	5	1	5	5	16	6	H
	Continuous glare from rig operations		√	√		√		√		0	1	3	1	1	6	4	L
	Opportunities for business and employment	√		√		√	√	√		-	-	-	-	-	-	-	P
	Increased oil production	√		√		√	√	√		-	-	-	-	-	-	-	P
	Increased revenue	√		√		√	√	√		-	-	-	-	-	-	-	P
	Impairment of water and sediment quality from accidental release of hydrocarbons, drill cuttings		√	√		√		√		3	3	3	3	3	15	6	H
	Increased waste volumes - drilling cuttings and muds		√	√		√		√		5	3	3	3	3	17	6	H
	Smothering of benthic flora and fauna		√	√		√		√		0	1	1	3	1	6	4	L
	Interference with marine wildlife		√	√		√		√		0	1	1	3	1	6	4	L
	Accidents and injuries from anchor and mooring failures, crane accidents,		√	√		√	√	√	√	0	5	3	5	5	18	8	H

Project phase/Activity	Impacts	Impact Description				Impact Qualification				Impact Quantification							Impact Rating
		Positive	Negative	Direct	Indirect	Short term	Long term	Reversible	Irreversible	L	R	F	I	P	Total	F+I	
	machinery/propulsion failure , dropped objects																
	Accidental ignition of released hydrocarbons		√	√		√	√	√	√	0	5	3	5	5	18	8	H
	Structural failures due to fatigue – Derrick collapse, crane collapse,		√	√		√	√	√	√	0	5	1	5	5	16	6	H
	Risk of dropped objects during lifting and hoisting activities		√	√		√	√	√	√	0	5	1	5	5	16	6	H
Demobilization	Impairment of air quality		√	√		√		√		3	1	1	3	5	13	4	M
	Water traffic incidents		√	√		√	√	√	√	0	3	3	3	3	12	6	H
	Improper disposal of materials removed from site		√	√		√	√	√		3	3	1	3	3	13	4	M
	Increase in noise and vibration level		√	√		√		√		3	3	1	3	1	11	4	M
	Loss of employment/ income		√	√		√	√	√	√	0	5	3	3	5	16	6	H
	Risk of accident from vessel collision		√	√		√	√	√	√	0	3	3	3	3	12	6	H
	Risk of Piracy & kidnapping		√	√		√	√	√	√	0	5	3	5	5	18	8	H

Project phase/Activity	Impacts	Impact Description				Impact Qualification				Impact Quantification							Impact Rating
		Positive	Negative	Direct	Indirect	Short term	Long term	Reversible	Irreversible	L	R	F	I	P	Total	F+I	
	Interference with water transport and fishing activities		√	√		√		√		0	1	1	1	3	6	2	L
Commissioning	Increase in Business opportunities	√		√			√	√		-	-	-	-	-	-	-	P
	Air quality impairment from Well flare/vent		√	√		√		√		3	3	1	3	1	11	4	M
	Increase in noise & vibration nuisance		√	√		√		√		3	3	1	3	1	11	4	M
	Risk of Piracy & kidnapping		√	√		√	√	√	√	0	5	3	5	5	18	8	H
Operations and Maintenance Well work-over, Gas production,	Improper disposal of materials		√	√		√	√	√	√	3	3	3	3	3	15	6	H
	Revenue generation to government and company	√		√			√	√		-	-	-	-	-	-	-	P
	Increase in noise levels		√	√			√	√		3	1	1	1	1	7	2	L
	Air quality impairment from Well flare/vent		√	√		√	√	√		5	3	5	5	3	21	10	H
	Risk of Piracy & kidnapping		√	√		√	√	√	√	0	5	3	5	5	18	8	H
	Leaks from Well head equipment and flanges		√	√		√	√	√	√	0	5	3	5	5	18	8	H
Decommissioning and Abandonment	Employment and income generating opportunity	√		√		√		√		-	-	-	-	-	-	-	P

Project phase/Activity	Impacts	Impact Description				Impact Qualification				Impact Quantification							Impact Rating
		Positive	Negative	Direct	Indirect	Short term	Long term	Reversible	Irreversible	L	R	F	I	P	Total	F+I	
	Increase in noise and vibration		√	√		√		√		3	3	1	3	1	11	4	M
	Interference with water transport and fishing activities		√	√		√		√		0	1	1	1	3	6	2	L
	Impairment of air quality from emission of HWR		√	√		√		√		3	1	1	1	1	8	2	M
	Risk of accident from well blowout during decommissioning		√	√		√	√	√	√	0	3	3	3	3	12	6	H
	Risk of Piracy & kidnapping		√	√		√	√	√	√	0	5	3	5	5	18	8	H
	Increase potential for water traffic accidents/ injury		√	√		√	√	√	√	3	1	1	3	1	9	4	M
	Potential for conflicts arising from labour issues		√	√		√		√		0	1	3	5	5	16	8	H
	Impairment of surface water and sediment quality from complete decommissioning activities		√	√		√		√		3	3	1	3	3	13	4	M
	Disruption of aquatic fauna community		√	√		√		√		0	3	1	3	1	8	4	M

Project phase/Activity	Impacts	Impact Description				Impact Qualification				Impact Quantification							Impact Rating
		Positive	Negative	Direct	Indirect	Short term	Long term	Reversible	Irreversible	L	R	F	I	P	Total	F+I	
	Interference with marine wildlife		√	√		√		√		0	1	1	1	1	4	2	L
	Injury/fatalities in workforce		√	√		√	√	√	√	3	3	1	3	3	13	4	H

CHAPTER SIX
MITIGATION MEASURES

6.1: Introduction

The action plans and measures SPDC propose to take to reduce (or eliminate) negative impacts and promote positive impacts of the proposed Project are presented in this chapter. In proffering mitigation measures, emphases are placed on those negative impacts rated as significant (medium and high impacts). The measures are aimed at reducing potential impacts to As Low As Reasonably Practicable (ALARP). The residual impacts that could arise despite these mitigation measures were also noted. None significant impacts are expected to be mitigated through effective implementation of Health, Safety and Environment (HSE) plans that will be put in place during the different phases of the project.

The mitigation measures proposed are in consonance with the following:

- Department of Petroleum Resources guidelines and standards,
- National, regional and international Environmental laws,
- Best Available Technology for Sustainable Development;
- Social wellbeing and
- Concerns of stakeholders.

The following criteria were used to define mitigation measures for the identified impacts:

- Prevention - Exclude significant potential impacts and risks by design and management Measures.
- Reduction - Minimize the effects or consequences of those significant associated and potential impacts that cannot be prevented, to a level as low as reasonably practicable by implementing operational and management measures.
- Control - Implement operational and management measures to ensure that residual associated impacts are reduced to a level as low as reasonably practicable.

6.2: Mitigation Measures

A summary of the mitigation measures for the potential, associated and existing impacts is presented in Table 6.1. These measures are recommended to ameliorate all the significant impacts of existing facilities and significant associated and potential impacts for the proposed Project.

Table 6.1: Mitigation Measures for Significant Project Impacts

Project Phase	**Description of Impacts**	**Impact Rating Before Mitigation**	**Mitigation Measures**	**Impact Rating After Mitigation**
Pre-mobilization Survey Consultation	Risk of accident from vessel collision	H	SPDC shall ensure • Compliance with journey management policy marine transport • Adequate radio communication between offshore installations, merchant ships and standby vessels • Communication hardwares and agreed Global Maritime Distress and Safety System (GMDSS) procedures are effective • Regular drills on abandon ship procedures shall be enforced • Daily pep talk shall be conducted • Safety signages shall be deployed at strategic locations. • Activate Emergency response plan inline with SOLAS • Use of appropriate PFDs by the survey team.	L
	Risk of Piracy and kidnapping	H	SPDC shall: • Proper identification and management for all security threats and risk are highlighted • Develop adequate security strategy, plan and procedure for the project. • Ensure that security orientation and awareness/drills are conducted for the workforce • Make all necessary arrangements with Government security agents to improve security. • Develop security management plan for the project before mobilization.	M

Project Phase	Description of Impacts	Impact Rating Before Mitigation	Mitigation Measures	Impact Rating After Mitigation
			• Ensure all countermeasures to mitigate identified threats are in place. • Ensure project non productive time are reduced to the barest minimum. • Regular drills are conducted. • All movements shall be undertaken only with Security Single Point Approval • Movement shall be under a GSA armed escort.	
Mobilization (equipment and personnel), and Rig Movement	Impairment of air quality	M	SPDC shall: • Use only pre-mobbed and regularly maintained vessels, generators and other machines. • Use only low Sulphur containing fuels and low NOx burners in large generators and turbines. • Ensure wet scrubbers and venturi techniques are fitted at the end of pipe for generators and vessel exhaust systems	L
	Increase in noise and vibration	M	SPDC shall • use only pre-mobbed and regularly maintained equipment and water crafts. • Ensure availability and use of proper PPE by workforce • Provide acoustic mufflers for heavy engines with noise level above acceptable limits • Daily pep talk is carried out for workforce	L
	Risk of accident	H	SPDC shall ensure: • Adequate radio communication between offshore installations, merchant ships and standby vessels	L

Project Phase	Description of Impacts	Impact Rating Before Mitigation	Mitigation Measures	Impact Rating After Mitigation
			• Communication hardwares and agreed Global Maritime Distress and Safety System (GMDSS) procedures are effective • Regular drills on abandon ship procedures shall be enforced • Safety signages shall be deployed at strategic locations. • Activate Emergency response plan inline with SOLAS • Strict adherence to weather forecast information from the synoptic stations. • Only competent and experienced vessel crew with appropriate certification shall be used.	
	Risk of Piracy and kidnapping	H	SPDC shall: • Proper identification and management for all security threats and risk are highlighted • Develop adequate security strategy, plan and procedure for the project. • Ensure that security orientation and awareness/drills are conducted for the workforce • Make all necessary arrangements with Government security agents to improve security. • Develop security management plan for the project before mobilization. • Ensure all countermeasures to mitigate identified threats are in place. • Ensure project non productive time are reduced to the barest minimum.	M

Project Phase	Description of Impacts	Impact Rating Before Mitigation	Mitigation Measures	Impact Rating After Mitigation
			• Regular drills are conducted. • All movements shall be undertaken only with Security Single Point Approval • Movement shall be under a GSA armed escort.	
Site preparation (piling)	Increase in noise and vibration	H	SPDC shall ensure: • Appropriate pile techniques are used to minimize noise and vibration effects and disturbance of marine life. • Only pre-mob of all equipment before they are deployed to site. • Use Generators with noise levels within acceptable limits of (85 - 90 dB (A). • Appropriate abatement techniques are adopted including the use of acoustic mufflers for heavy engines with noise level above acceptable limits. • Enclose high sound energy equipment in noise insulators in line with SPDC policy. • SPDC HSE policy of wearing ear muffs/ plugs shall be applied during piling activities. • Sufficient separation distances shall be provided for sources of high-energy sound to reduce noise levels. • Workers with existing hearing impairment shall not be deployed to site.	L
	Fish-kills during piling activity	H	SPDC shall: • Ensure the use of Best Practical Environmental Option shall be adopted to minimize disturbance of fish and other marine fauna	L

Project Phase	Description of Impacts	Impact Rating Before Mitigation	Mitigation Measures	Impact Rating After Mitigation
			• Ensure pile driving activities commence slowly to provide opportunities for migration of marine fauna. • Mobilize to site during off season to avoid disruption of some marine organisms` reproduction cycle and migratory routes.	
	Risk of accident from dropped objects and structural failures	H	SPDC shall ensure: • Enforce the prohibition of untethered tools, uncertified lifing equipment, bolt secured with a double nut arrangements etc. • Effective inspection and audit of drop object prevention programme. • Effective housekeeping practices are implemented and maintained. • Working at height procedures shall be implemented. • All designated dropped object risk control zones are to be access controlled. • The use of appropriate PPEs during piling activities • Safety signages are deployed at strategic locations. • Emergency response plan are in place.	L
	Risk of Piracy and kidnapping	H	SPDC shall: • Activate countermeasures to mitigate the threats of piracy and kidnapping. • Ensure project non productive time is reduced to the barest minimum. • All movements shall be undertaken only with Security Single Point Approval	M

Project Phase	**Description of Impacts**	**Impact Rating Before Mitigation**	**Mitigation Measures**	**Impact Rating After Mitigation**
			• All piling activities are executed under a GSA armed escort.	
	Fish-kills	M	SPDC shall: • Ensure the use of Best Practical Environmental Option shall be adopted to minimize disturbance of fish and other marine fauna • Ensure pile driving activities commence slowly to provide opportunities for migration of marine fauna. • Mobilize to site during off season to avoid disruption of some marine organisms` reproduction cycle and migratory routes.	L
	Aggregation of bottom sediments	M	SPDC shall use the best available technology to minimize disturbance of bottom sediments	L
	Impairment of water quality (turbidity and suspended solids)	M	• Deploy best in class pile driving technique to reduce impact of turbidity	L
Installation and positioning of Wellhead Platform	Increase in noise and vibration	H	SPDC shall ensure: • Acoustic mufflers shall be provided for heavy engines with noise level above acceptable limits • High sound energy equipment shall be enclosed in noise insulators in line with SPDC policy • SPDC HSE policy of wearing ear muffs/ plugs shall be applied in all construction and operational sites where high noise is produced. • Sufficient separation distances shall be provided for sources of high-energy sound to reduce noise levels.	L
	Interference with fishing activities	M	SPDC shall:	L

Project Phase	Description of Impacts	Impact Rating Before Mitigation	Mitigation Measures	Impact Rating After Mitigation
			• Provide timely information to stakeholders particularly fisher folk on the nature and timing of activities which may lead to direct interference with fishing activities/operations.	
	Risk of accident from lifting and hoisting activities	H	SPDC shall: • Ensure the certification of lifting equipment • Conduct strength test for lifting slings • Dynamic Risk assessment conducted for SIMOPS. • Enforce the prohibition of untethered tools, uncertified lifting equipment, bolt secured with a double nut arrangement etc. • Effective inspection and audit of drop object prevention programme. • Effective housekeeping practices are implemented and maintained. • Working at height procedures shall be implemented. • All designated dropped object risk control zones are to be access controlled. • The use of appropriate PPEs during installation of Well head platforms • Safety signages are deployed at strategic locations. • Emergency response plan are in place	L
	Risk of Piracy and kidnapping	H	SPDC shall: • Activate countermeasures to mitigate the threats of piracy and kidnapping.	M

Project Phase	Description of Impacts	Impact Rating Before Mitigation	Mitigation Measures	Impact Rating After Mitigation
			• Ensure project non productive time is reduced to the barest minimum. • All movements shall be undertaken only with Security Single Point Approval • All installation activities are executed under a GSA armed escort.	
	Impacts of Wastes (metal scrap)	H	SPDC shall ensure: • Wastes are segregated at source inline with the SPDC Waste Management Plan. • Scrap metal/pipe off-cuts are transported to Shell Kidney Island (KI) scrap yard, Port Harcourt, for onward delivery to SPDC approved metal recycling vendor(s).	L
	Duty of care extended to Contractor yard	P	SPDC shall occasionally visit contractor`s yard during fabrication activities	P
Drilling	Impairment of air quality	M	SPDC shall ensure: • generators and engines are maintained in accordance with written procedures based on the manufacturers' guidelines or applicable industry code or engineering standards to ensure efficient and reliable operation. • Regular audits of drilling operation.	L
	Noise and vibration nuisance	M	SPDC shall ensure that: • Appropriate technology (Big Air Bubble Curtain, Noise Mitigation Screen, Acoustic decoupling (vibration absorber) to mimimize the impact of noise and vibration.	L

Project Phase	Description of Impacts	Impact Rating Before Mitigation	Mitigation Measures	Impact Rating After Mitigation
			• Soft start protocols are adopted for drilling activities (Noise emissions shall begin at low power, increasing gradually until full power is reached). • Acoustic Mitigation devices shall be used to drive away marine mammals • SPDC HSE policy of wearing ear muffs/ plugs is applied in all construction and operational sites where high noise is produced.	
	Injuries and death from failure of BOP	H	SPDC shall ensure that: • Well design approach incorporates protection against credible risks associated with the drilling and completion processes. • All primary cemented barriers to flow shall be tested to verify quality, quantity and location of cement. • The integrity of primary mechanical barriers (such as the float equipment, liner tops and wellhead seals) shall be verified by using best available test procedures. • BOP systems shall be designed to provide a robust and reliable cutting, sealing and separation capabilities for the drilling environment. • Test and maintenance procedures shall be established to ensure operability and reliability to their environment of application. • Instrumentation and expert system decision aids shall be used to provide timely warning of loss of well control to drillers on the rig.	M

Project Phase	Description of Impacts	Impact Rating Before Mitigation	Mitigation Measures	Impact Rating After Mitigation
			• Use appropriate blowout prevention fluids. • Use appropriate mud density. • Ensure emergency response procedures are in place.	
	Impairment of water and sediment quality from accidental release of hydrocarbons, drill cuttings	H	• SPDC shall continue to encourage the use of WBM in her drilling programme. • In the event that large quantities of hydrocarbon are produced during the proposed well and reservoir test, the hydrocarbons will be evacuated to the FPSO.	L
	Increased waste volumes - drilling cuttings and muds	H	• Cuttings and the associated fluids shall be collected and transported for treatment if necessary and final disposal. • SPDC shall encourage waste-to-shore programme for treatment and disposal.	L
	Smothering of benthic flora and fauna	H	• SPDC shall encourage waste-to-shore programme for treatment and disposal of drilling mud and cuttings.	L
	Interference with marine wildlife	H	• Soft start protocols are adopted for drilling activities (Noise emissions shall begin at low power, increasing gradually until full power is reached). • Acoustic Mitigation devices shall be used to drive away marine mammals	L
	Accidents and injuries from anchor and mooring failures, crane accidents, machinery/propulsion failure,	H	SPDC shall ensure: • All rotating parts of the mooring equipment shall be free running and the grease nipples should be clearly marked so they are not missed during greasing rounds • The crew members are competent • Enforce the use of appropriate PPEs	L

Project Phase	Description of Impacts	Impact Rating Before Mitigation	Mitigation Measures	Impact Rating After Mitigation
			• Lines/machinery are inspected regularly, paying attention to wear and tear, thermal damage and dirt.	
	Accidental ignition of released hydrocarbons	H	SPDC shall: • Activate emergency response plan • use of water deluge system to control pool fires and reduce the risk of escalation, provide cooling of equipment not impinged by jet fires, and limit the effects of fires to make evacuation possible.	L
	Structural failures due to fatigue – Derrick collapse, crane collapse,	H	SPDC shall: • Ensure the certification of lifting equipment • Conduct strength test for lifting slings • Regular maintenance of equipment to prevent corrosion either by selection of corrosion resistant materials or by application of suitable protective techniques or coatings in accordance to international best practices and manufacturers guidelines. • Effective inspection and audit of drop object prevention programme. • All designated dropped object risk control zones are to be access controlled. • The use of appropriate PPEs during drilling phase. • Safety signages are deployed at strategic locations. • Emergency response plan are in place	L
	Risk of dropped objects during lifting and hoisting activities	H	SPDC shall: • Ensure the certification of lifting equipment • Conduct strength test for lifting slings	L

Project Phase	Description of Impacts	Impact Rating Before Mitigation	Mitigation Measures	Impact Rating After Mitigation
			• Dynamic Risk assessment conducted for SIMOPS. • Enforce the prohibition of untethered tools, uncertified lifting equipment, bolt secured with a double nut arrangements etc. • Effective inspection and audit of drop object prevention programme. • Effective housekeeping practices are implemented and maintained. • Working at height procedures shall be implemented. • All designated dropped object risk control zones are to be access controlled. • The use of appropriate PPEs during installation of Well head platforms • Safety signages are deployed at strategic locations. • Emergency response plan are in place	
Demobilization	Impairment of air quality (VOC & SPM)	M	SPDC shall: • Use only pre-mobbed and regularly maintained vessels, generators and other machines. • Use only low Sulphur containing fuels and low NOx burners in large generators and turbines. • Ensure wet scrubbers and venturi techniques are fitted at the end of pipe for generators and vessel exhaust systems	L
	Water traffic incidents	H	SPDC shall ensure: • Adequate radio communication between offshore installations, merchant ships and standby vessels	L

Project Phase	Description of Impacts	Impact Rating Before Mitigation	Mitigation Measures	Impact Rating After Mitigation
			• Communication hardwares and agreed Global Maritime Distress and Safety System (GMDSS) procedures are effective • Regular drills on abandon ship procedures shall be enforced • Safety signages shall be deployed at strategic locations. • Activate Emergency response plan inline with SOLAS • Strict adherence to weather forecast information from the synoptic stations. • Only competent and experienced vessel crew with appropriate certification shall be used.	
	Improper disposal of materials removed from site	M	SPDC shall ensure: • All removed materials shall be properly disposed of and monitored from cradle to grave in line with the waste management plan • Scrap metals shall be collected, segregated and subjected to SPDC's waste management guidelines. • Plastic wastes shall be sent to an approved Recycling Waste Depot (RWD). • Radioactive wastes/materials shall be managed according to Nigerian Nuclear Regulatory Authority (NNRA) approved procedure. • SPDC waste management policy shall be enforced.	L
	Increase in noise and vibration level	M	SPDC shall: Use only pre-mobbed and regularly maintained equipment and water crafts	L

Project Phase	Description of Impacts	Impact Rating Before Mitigation	Mitigation Measures	Impact Rating After Mitigation
	Loss of employment/ income	H	SPDC Shall: • Strengthen existing cooperation of the neighboring communities via the existing Global Memorandum of Association interface. • Require contractors to prepare and implement workers disengagement plans • Encourage and support skill acquisition programmes of Government, NGOs and CBOs	L
	Risk of accident from vessel collision	H	SPDC shall ensure: • Adequate radio communication between offshore installations, merchant ships and standby vessels • Communication hardwares and agreed Global Maritime Distress and Safety System (GMDSS) procedures are effective • Regular drills on abandon ship procedures shall be enforced • Safety signages shall be deployed at strategic locations. • Activate Emergency response plan in line with SOLAS • Strict adherence to weather forecast information from the synoptic stations. • Only competent and experienced vessel crew with appropriate certification shall be used.	L
	Risk of Piracy & kidnapping	H	SPDC shall: • Activate countermeasures to mitigate the threats of piracy and kidnapping.	M

Project Phase	Description of Impacts	Impact Rating Before Mitigation	Mitigation Measures	Impact Rating After Mitigation
			• Ensure project non productive time is reduced to the barest minimum. • All movements shall be undertaken only with Security Single Point Approval • All installation activities are executed under the supervision of a GSA armed escort.	
Commissioning	Increase in Business opportunities	P	SPDC shall ensure adherence to local content policy	P
	Air quality impairment from Well flare/vent	M	SPDC shall ensure limit flaring/venting to ALARP.	L
	Risk of influx of Commercial Sex Workers to surrounding communities with resultant increase in rates of Sexually Transmitted Infections	M	Community Health shall conduct sexual and reproductive health awareness campaigns.	L
	Risk of Piracy & kidnapping	H	SPDC shall: • Activate countermeasures to mitigate the threats of piracy and kidnapping. • Ensure project non productive time is reduced to the barest minimum. • All movements shall be undertaken only with Security Single Point Approval • All installation activities are executed under the supervision of a GSA armed escort.	M
Operations and Maintenance	Improper disposal of materials removed from site	H	SPDC shall: • Ensure all oily wastes are properly segregated and contained before disposal.	L

Project Phase	Description of Impacts	Impact Rating Before Mitigation	Mitigation Measures	Impact Rating After Mitigation
			• Ensure all oily wastes are properly disposed of and monitored from cradle to grave. • Ensure regular clean-up of equipment at site. • Provide containment for chemicals and liquid discharges. • Ensure the enforcement of waste management policy. • Ensure that a controlled fuelling, maintenance and servicing protocol for machinery at worksite is established and followed to minimize leaks and spills. • Ensure Spent chemicals, lube oil, grease, waste oil and detergent solutions are properly disposed of. • Ensure used chemical drums and containers are sent to an approved recyclable waste dump (RWD). • Ensure that Small chemicals spills, crude oil and aqueous effluents shall be cleaned up promptly.	
	Equipment failure and damage leading to injuries/fatality	M	SPDC shall ensure that: • Only skilled personnel and certified equipment are used. • Certified first aiders shall be available at every site. • First aid boxes and emergency response procedures are in place. • Hazard assessment has been conducted. • Emergency response procedures are in place. • HSE standards are strictly adhered to. • Permit to work and proper briefing is giving before any work can commence.	L
	Air quality impairment from Well flare/vent	H	SPDC shall ensure limit flaring/venting to ALARP.	L

Project Phase	Description of Impacts	Impact Rating Before Mitigation	Mitigation Measures	Impact Rating After Mitigation
	Risk of Piracy & kidnapping	H	SPDC shall: • Activate countermeasures to mitigate the threats of piracy and kidnapping. • Ensure project non productive time is reduced to the barest minimum. • All movements shall be undertaken only with Security Single Point Approval • All installation activities are executed under the supervision of a GSA armed escort.	M
	Leaks from Well head equipment and flanges		SPDC shall: • Ensure adequate testing of pipes and values for leakages prior to introduction of hydrocarbon. • Installation of Emergency Shut down Valve (ESDV) to control excessive well pressure.	
Decommissioning and Abandonment	Increase in noise and vibration	M	SPDC shall • Use only pre-mobbed and regularly maintained equipment and water crafts	L
	Impairment of air quality from emission of HWR	M	SPDC shall: • Use only pre-mobbed crafts • Regular maintenance of water crafts, vessels, generators and other machines. • Use low sulphur containing fuel and low NOx burners	L
	Risk of Piracy & kidnapping	H	SPDC shall: • Activate countermeasures to mitigate the threats of piracy and kidnapping.	M

Project Phase	Description of Impacts	Impact Rating Before Mitigation	Mitigation Measures	Impact Rating After Mitigation
			• Ensure project non-productive time is reduced to the barest minimum. • All movements shall be undertaken only with Security Single Point Approval • All installation activities are executed under the supervision of a GSA armed escort.	
	Increase potential for water traffic accidents/ injury	M	SPDC shall ensure: • Adequate radio communication between offshore installations, merchant ships and standby vessels • Communication hardwares and agreed Global Maritime Distress and Safety System (GMDSS) procedures are effective • Regular drills on abandon ship procedures shall be enforced • Safety signages shall be deployed at strategic locations. • Activate Emergency response plan inline with SOLAS • Strict adherence to weather forcast information from the synoptic stations. • Only competent and experienced vessel crew with appropriate certification shall be used.	L
	Potential for conflicts arising from labour issues	H	SPDC and her contractors shall: • Respond to complaints by locals on the activities of her workers. • Deploy GMOU provisions on community employment.	L
	Injury/fatalities in workforce	H	SPDC shall ensure: • Daily pep talk is carried out for marine transportation	L

Project Phase	**Description of Impacts**	**Impact Rating Before Mitigation**	**Mitigation Measures**	**Impact Rating After Mitigation**
			• Safety signage shall be deployed at strategic locations. • Provide first aid boxes in operational water crafts. • Emergency response plan shall be in place.	
	Impairment of surface water and sediment quality from complete decommissioning activities	H	SPDC shall ensure that: • Effluents from decommissioning activities are treated to regulatory standards before discharge.	L

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 JK Exploration and Appraisal Wells Project (premobilization, mobilization, drilling, demobilization, operation and decommissioning) activities are mainly food wastes, garbage, scrap metals and drill cuttings/fluids. 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;
- 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 7.1a: Environmental Management Plan for the JK Exploration and Appraisal Wells Project - Premobilization phase

Project activity	Description of Impacts	Impact Rating Before Mitigation	Mitigation Measures	Impact Rating After Mitigation	Parameter for Monitoring	Frequency of Monitoring	Responsible/ Action Party
Survey Consultation	Risk of accident from vessel collision	H	SPDC shall ensure: • Compliance with journey management policy marine transport • Adequate radio communication between offshore installations, merchant ships and standby vessels • Communication hardwares and agreed Global Maritime Distress and Safety System (GMDSS) procedures are effective • Regular drills on abandon ship procedures shall be enforced • Daily pep talk shall be conducted • Safety signages shall be deployed at strategic locations. • Activate Emergency response plan inline with SOLAS • Use of appropriate PFDs by the survey team.	L	• Journey management records • Pre-mob certificates of vessels • Pep-talk records • Accident records	Monthly during premobilization	Project manager/DPR/ FMEnv
	Risk of Piracy and kidnapping	H	SPDC shall: • Proper identification and management for all security threats and risk are highlighted • Develop adequate security strategy, plan and procedure for the project. • Ensure that security orientation and awareness/drills are conducted for the workforce	M	• Security Management procedure • Journey management procedure • Record of security situation/ updates	Monthly during premobilization	Project manager/DPR/ FMEnv

Project activity	Description of Impacts	Impact Rating Before Mitigation	Mitigation Measures	Impact Rating After Mitigation	Parameter for Monitoring	Frequency of Monitoring	Responsible/ Action Party
			• Make all necessary arrangements with Government security agents to improve security. • Develop security management plan for the project before mobilization. • Ensure all countermeasures to mitigate identified threats are in place. • Ensure project nonproductive time are reduced to the barest minimum. • Regular drills are conducted. • All movements shall be undertaken only with Security Single Point Approval • Movement shall be under a GSA armed escort.		• Site Inspection records		

Table 7.1b: Environmental Management Plan for the JK Exploration and Appraisal Wells Project - Mobilization phase

Project activity	Description of Impacts	Impact Rating Before Mitigation	Mitigation Measures	Impact Rating After Mitigation	Parameter for Monitoring	Frequency of Monitoring	Responsible/ Action Party
Mobilization (equipment and personnel), and Rig Movement	Impairment of air quality	M	SPDC shall: • Use only pre-mobbed and regularly maintained vessels, generators and other machines. • Use only low sulphur containing fuels and low NOx burners in large generators and turbines. • Ensure wet scrubbers and venturi techniques are fitted at the end of pipe for generators and vessel exhaust systems	L	• Premob certificates • Maintenance records	Weekly during mobilization	Project manager/DPR/ FMEnv
	Increase in noise and vibration	M	SPDC shall • use only pre-mobbed and regularly maintained equipment and water crafts. • Ensure availability and use of proper PPE by workforce • Provide acoustic mufflers for heavy engines with noise level above acceptable limits • Daily pep talk is carried out for workforce	L	• Premob certificates • Maintenance records	Weekly during mobilization	Project manager/DPR/FMEnv
	Risk of accident	H	SPDC shall ensure: • Adequate radio communication between offshore installations, merchant ships and standby vessels • Communication hardwares and agreed Global Maritime Distress	L	• Journey management records • Premob certificates • Pep-talk records • Accident records	Monthly	Project manager/DPR/FMEnv

Project activity	Description of Impacts	Impact Rating Before Mitigation	Mitigation Measures	Impact Rating After Mitigation	Parameter for Monitoring	Frequency of Monitoring	Responsible/ Action Party
			and Safety System (GMDSS) procedures are effective • Regular drills on abandon ship procedures shall be enforced • Safety signages shall be deployed at strategic locations. • Activate Emergency response plan inline with SOLAS • Strict adherence to weather forecast information from the synoptic stations. • Only competent and experienced vessel crew with appropriate certification shall be used.				
	Risk of Piracy and kidnapping	H	SPDC shall: • Activate countermeasures to mitigate the threats of piracy and kidnapping. • Ensure project nonproductive time is reduced to the barest minimum. • All movements shall be undertaken only with Security Single Point Approval.	M	• Security Management procedure • Record of security situation/ updates • Site Inspection records	Monthly	Project manager/DPR/FMEnv

Table 7.1c: Environmental Management Plan for the JK Exploration and Appraisal Wells Project - Construction phase

Project activity	Description of Impacts	Impact Rating Before Mitigation	Mitigation Measures	Impact Rating After Mitigation	Parameter for Monitoring	Frequency of Monitoring	Responsible/ Action Party
Site preparation (piling)	Increase in noise and vibration	H	SPDC shall ensure: • Appropriate pile techniques are used to minimize noise and vibration effects and disturbance of marine life. • Only pre-mob of all equipment before they are deployed to site. • Use Generators with noise levels within acceptable limits of (85 - 90 dB (A). • Appropriate abatement techniques are adopted including the use of acoustic mufflers for heavy engines with noise level above acceptable limits. • Enclose high sound energy equipment in noise insulators in line with SPDC policy. • SPDC HSE policy of wearing ear muffs/ plugs shall be applied during piling activities. • Sufficient separation distances shall be provided for sources of high-energy	L	• Premob certificates • Maintenance records	Weekly	Project manager/DPR/FMEnv

Project activity	Description of Impacts	Impact Rating Before Mitigation	Mitigation Measures	Impact Rating After Mitigation	Parameter for Monitoring	Frequency of Monitoring	Responsible/ Action Party
			sound to reduce noise levels. • Workers with existing hearing impairment shall not be deployed to site.				
	Fish-kills during piling activity	H	SPDC shall: • Ensure the use of Best Practical Environmental Option shall be adopted to minimize disturbance of fish and other marine fauna • Ensure pile driving activities commence slowly to provide opportunities for migration of marine fauna. • Mobilise to site during off season to avoid disruption of some marine organisms` reproduction cycle and migratory routes.	L	• Site inspection report	Once during piling activity	Project manager/DPR/FMEnv
	Risk of accident from dropped objects and structural failures	H	SPDC shall ensure: • Enforce the prohibition of untethered tools, uncertified lifing equipment, bolt secured with a double nut arrangements etc. • Effective inspection and audit of drop object prevention programme.	L	• Premob certificates • Pep-talk records • Accident records	Monthly	Project manager/DPR/FMEnv

Project activity	Description of Impacts	Impact Rating Before Mitigation	Mitigation Measures	Impact Rating After Mitigation	Parameter for Monitoring	Frequency of Monitoring	Responsible/ Action Party
			• Effective housekeeping practices are implemented and maintained. • Working at height procedures shall be implemented. • All designated dropped object risk control zones are to be access controlled. • The use of appropriate PPEs during piling activities • Safety signages are deployed at strategic locations. • Emergency response plan are in place.				
	Risk of Piracy and kidnapping	H	SPDC shall: • Activate countermeasures to mitigate the threats of piracy and kidnapping. • Ensure project non productive time is reduced to the barest minimum. • All movements shall be undertaken only with Security Single Point Approval	M	• Security Management procedure • Record of security situation/ updates • Site Inspection records	Monthly	Project manager/DPR/FMEnv

Project activity	Description of Impacts	Impact Rating Before Mitigation	Mitigation Measures	Impact Rating After Mitigation	Parameter for Monitoring	Frequency of Monitoring	Responsible/ Action Party
			• All piling activities are executed under a GSA armed escort.				
	Aggregation of bottom sediments	M	• SPDC shall use the best available technology to minimize disturbance of bottom sediments	L	• Site inspection report	Once during piling activity	Project manager/DPR/FMEnv
	Impairment of water quality (turbidity and suspended solids)	M	• Deploy best in class pile driving technique to reduce impact of turbidity	L	• Site inspection report	Monthly	Project manager/DPR/FMEnv
Installation and positioning of Wellhead Platform	Increase in noise and vibration	H	SPDC shall ensure: • Acoustic mufflers shall be provided for heavy engines with noise level above acceptable limits • High sound energy equipment shall be enclosed in noise insulators in line with SPDC policy • SPDC HSE policy of wearing ear muffs/ plugs shall be applied in all construction and operational sites where high noise is produced. • Sufficient separation distances shall be provided for sources of high-energy	L	• Premob certificates • Maintenance records	Weekly	Project manager/DPR/FMEnv

Project activity	Description of Impacts	Impact Rating Before Mitigation	Mitigation Measures	Impact Rating After Mitigation	Parameter for Monitoring	Frequency of Monitoring	Responsible/ Action Party
			sound to reduce noise levels.				
	Interference with fishing activities	M	SPDC shall: • Provide timely information to stakeholders particularly fisher folk on the nature and timing of activities which may lead to direct interference with fishing activities/operations.	L	Records of engagement sessions	Once during piling activity	Project manager/DPR/FMEnv
	Risk of accident from lifting and hoisting activities	H	SPDC shall: • Ensure the certification of lifting equipment • Conduct strength test for lifting slings • Dynamic Risk assessment conducted for SIMOPS. • Enforce the prohibition of untethered tools, uncertified lifing equipment, bolt secured with a double nut arrangements etc. • Effective inspection and audit of drop object prevention programme. • Effective housekeeping practices are implemented and maintained.	L	• Journey management records • Premob certificates • Pep-talk records • Accident records	Monthly	Project manager/DPR/FMEnv

Project activity	Description of Impacts	Impact Rating Before Mitigation	Mitigation Measures	Impact Rating After Mitigation	Parameter for Monitoring	Frequency of Monitoring	Responsible/ Action Party
			• Working at height procedures shall be implemented. • All designated dropped object risk control zones are to be access controlled. • The use of appropriate PPEs during installation of Well head platforms • Safety signages are deployed at strategic locations. • Emergency response plan are in place				
	Risk of Piracy and kidnapping	H	SPDC shall: • Activate countermeasures to mitigate the threats of piracy and kidnapping. • Ensure project non productive time is reduced to the barest minimum. • All movements shall be undertaken only with Security Single Point Approval • All installation activities are executed under a GSA armed escort.	M	• Security Management procedure • Record of security situation/ updates • Site Inspection records	Monthly	Project manager/DPR/FMEnv

Project activity	Description of Impacts	Impact Rating Before Mitigation	Mitigation Measures	Impact Rating After Mitigation	Parameter for Monitoring	Frequency of Monitoring	Responsible/ Action Party
	Impacts of Wastes (metal scrap)	H	SPDC shall ensure: • Wastes are segregated at source inline with the SPDC Waste Management Plan. • Scrap metal/pipe off-cuts are transported to Shell Kidney Island (KI) scrap yard, Port Harcourt, for onward delivery to SPDC approved metal recycling vendor(s).	L	• SPDC Waste management plan • Waste consignment note • Environmental Compliance Monitoring Reports • Site inspection Reports	Weekly	Project manager/DPR/FMEnv
	Duty of care extended to Contractor yard	P	SPDC shall occasionally visit contractor`s yard during fabrication activities	P	• Safe system of work • JHA • Tool Box meeting • Work processes	Bi--monthly	Project manager/DPR/FMEnv

Table 7.1d: Environmental Management Plan for the JK Exploration and Appraisal Wells Project - Drilling

Project activity	Description of Impacts	Impact Rating Before Mitigation	Mitigation Measures	Impact Rating After Mitigation	Parameter for Monitoring	Frequency of Monitoring	Responsible/ Action Party
Drilling Drilling Campaign Casing and cementing Completion and perforation Well testing	Impairment of air quality	M	SPDC shall ensure: • generators and engines are maintained in accordance with written procedures based on the manufacturers' guidelines or applicable industry code or engineering standards to ensure efficient and reliable operation. • Regular audits of drilling operation.	L	• Premob certificates • Maintenance records	Weekly	Project manager/DPR/FMEnv
	Noise and vibration nuisance	M	SPDC shall ensure that: • Appropriate technology (Big Air Bubble Curtain, Noise Mitigation Screen, Acoustic decoupling (vibration absorber) to minimize the impact of noise and vibration. • Soft start protocols are adopted for drilling activities (Noise emissions shall begin at low power, increasing gradually until full power is reached). • Acoustic Mitigation devices shall be used to	L	• Premob certificates • Maintenance records	Weekly	Project manager/DPR/FMEnv

Project activity	Description of Impacts	Impact Rating Before Mitigation	Mitigation Measures	Impact Rating After Mitigation	Parameter for Monitoring	Frequency of Monitoring	Responsible/ Action Party
			drive away marine mammals • SPDC HSE policy of wearing ear muffs/ plugs is applied in all construction and operational sites where high noise is produced.				
	Injuries and death from failure of BOP and explosion	H	SPDC shall ensure that: • Well design approach incorporates protection against credible risks associated with the drilling and completion processes. • All primary cemented barriers to flow shall be tested to verify quality, quantity and location of cement. • The integrity of primary mechanical barriers (such as the float equipment, liner tops and wellhead seals) shall be verified by using best available test procedures. • BOP systems shall be designed to provide a robust and reliable cutting, sealing and separation capabilities	L	• Evidence of Equipment certification • Evidence of Cable and wire strength testing • Evidence of operator's competency • Issuance of PTW prior to the commencement of any activity on site.	Monthly	Project manager/DPR/FMEnv

Project activity	Description of Impacts	Impact Rating Before Mitigation	Mitigation Measures	Impact Rating After Mitigation	Parameter for Monitoring	Frequency of Monitoring	Responsible/ Action Party
			for the drilling environment. • Test and maintenance procedures shall be established to ensure operability and reliability to their environment of application. • Instrumentation and expert system decision aids shall be used to provide timely warning of loss of well control to drillers on the rig. • Use appropriate blowout prevention fluids. • Use appropriate mud density. • Ensure emergency response procedures are in place.				
	Impairment of water and sediment quality from accidental release of hydrocarbons, drill cuttings	H	• SPDC shall continue to encourage the use of WBM in her drilling programme. • In the event that large quantities of hydrocarbon are produced during the proposed well and reservoir test, SPDC shall activate an emergency response plan to curtain extent of spill	L	• Drill cutting treatment records • Drilling mud recovery record • Waste consignment note	Monthly	Project manager/DPR/FMEnv

Project activity	Description of Impacts	Impact Rating Before Mitigation	Mitigation Measures	Impact Rating After Mitigation	Parameter for Monitoring	Frequency of Monitoring	Responsible/ Action Party
	Increased waste volumes - drilling cuttings and muds		• Cuttings and the associated fluids shall be collected and transported for treatment if necessary and final disposal. • SPDC shall encourage waste-to-shore programme for treatment and disposal.	L	• SPDC Waste management plan • Waste consignment note • Site inspection Reports	Weekly	Project manager/DPR/FMEnv
	Smothering of benthic flora and fauna	H	• SPDC shall encourage waste-to-shore programme for treatment and disposal of drilling mud and cuttings.	L	• Drill cutting treatment records • Drilling mud recovery record	Monthly	Project manager/DPR/FMEnv
	Interference with marine wildlife	H	• Soft start protocols are adopted for drilling activities (Noise emissions shall begin at low power, increasing gradually until full power is reached). • Acoustic Mitigation devices shall be used to drive away marine mammals	L	• Site inspection report	Once during drilling activity	Project manager/DPR/FMEnv
	Accidents and injuries from anchor and mooring failures, crane accidents, machinery/propulsion failure,	H	• SPDC shall ensure: • All rotating parts of the mooring equipment shall be free running and the grease nipples should be clearly marked so they are not missed during greasing rounds	L	• Certification of workforce • MSDS and Technical specification • Emergency response plan	Weekly	Project manager/DPR/FMEnv

Project activity	Description of Impacts	Impact Rating Before Mitigation	Mitigation Measures	Impact Rating After Mitigation	Parameter for Monitoring	Frequency of Monitoring	Responsible/ Action Party
			• The crew members are competent • Enforce the use of appropriate PPEs • Lines/machinery are inspected regularly, paying attention to wear and tear, thermal damage and dirt.		• HAZID register. • Pep-talk records • Site inspection Reports		
	Accidental ignition of released hydrocarbons	M	SPDC shall: • Activate emergency response plan • use of water deluge system to control pool fires and reduce the risk of escalation, provide cooling of equipment not impinged by jet fires, and limit the effects of fires to make evacuation possible.	L	• Certification of workforce • MSDS and Technical specification • Emergency response plan • HAZID register. • Pep-talk records • Site inspection Reports	Weekly	Project manager/DPR/FMEnv
	Structural failures due to fatigue – Derrick collapse, crane collapse,	M	SPDC shall: • Ensure the certification of lifting equipment • Conduct strength test for lifting slings • Regular maintenance of equipment to prevent corrosion either by selection of corrosion	L	• Certification of workforce • MSDS and Technical specification • Emergency response plan • HAZID register.	Weekly	Project manager/DPR/FMEnv

Project activity	Description of Impacts	Impact Rating Before Mitigation	Mitigation Measures	Impact Rating After Mitigation	Parameter for Monitoring	Frequency of Monitoring	Responsible/ Action Party
			resistant materials or by application of suitable protective techniques or coatings in accordance to international best practices and manufacturers guidelines. • Effective inspection and audit of drop object prevention programme. • All designated dropped object risk control zones are to be access controlled. • The use of appropriate PPEs during drilling phase. • Safety signages are deployed at strategic locations. • Emergency response plan are in place		• Pep-talk records • Site inspection Reports		
	Risk of dropped objects during lifting and hoisting activities	M	SPDC shall: • Ensure the certification of lifting equipment • Conduct strength test for lifting slings • Dynamic Risk assessment conducted for SIMOPS. • Enforce the prohibition of untethered tools, uncertified lifting equipment, bolt	L	• Certification of workforce • MSDS and Technical specification • Emergency response plan • HAZID register.	Weekly	Project manager/DPR/FMEnv

Project activity	Description of Impacts	Impact Rating Before Mitigation	Mitigation Measures	Impact Rating After Mitigation	Parameter for Monitoring	Frequency of Monitoring	Responsible/ Action Party
			secured with a double nut arrangement etc. • Effective inspection and audit of drop object prevention programme. • Effective housekeeping practices are implemented and maintained. • Working at height procedures shall be implemented. • All designated dropped object risk control zones are to be access controlled. • The use of appropriate PPEs during installation of Well head platforms • Safety signages are deployed at strategic locations. • Emergency response plan are in place		• Pep-talk records • Site inspection Reports		

Table 7.1e: Environmental Management Plan for the JK Exploration and Appraisal Wells Project - Demobilization

Project activity	**Description of Impacts**	**Impact Rating Before Mitigation**	**Mitigation Measures**	**Impact Rating After Mitigation**	**Parameter for Monitoring**	**Frequency of Monitoring**	**Responsible/ Action Party**
Demobilization of rig, equipment and personnel	Impairment of air quality	M	SPDC shall: • Use only pre-mobbed and regularly maintained vessels, generators and other machines. • Use only low sulphur containing fuels and low NOx burners in large generators and turbines. • Ensure wet scrubbers and venturi techniques are fitted at the end of pipe for generators and vessel exhaust systems	L	• Premob certificates • Maintenance records •	Weekly	Project manager/DPR/FMEnv
	Water traffic incidents	H	SPDC shall ensure: • Adequate radio communication between offshore installations, merchant ships and standby vessels • Communication hardwares and agreed Global Maritime Distress and Safety System (GMDSS) procedures are effective • Regular drills on abandon ship procedures shall be enforced	L	• Journey management records • Premob certificates • Pep-talk records • Accident records	Weekly	Project manager/DPR/FMEnv

Project activity	Description of Impacts	Impact Rating Before Mitigation	Mitigation Measures	Impact Rating After Mitigation	Parameter for Monitoring	Frequency of Monitoring	Responsible/ Action Party
			• Safety signages shall be deployed at strategic locations. • Activate Emergency response plan inline with SOLAS • Strict adherence to weather forecast information from the synoptic stations. • Only competent and experienced vessel crew with appropriate certification shall be used.				
	Improper disposal of materials removed from site	M	SPDC shall ensure: • All removed materials shall be properly disposed of and monitored from cradle to grave in line with the waste management plan • Scrap metals shall be collected, segregated and subjected to SPDC's waste management guidelines. • Plastic wastes shall be sent to an approved Recycling Waste Depot (RWD). • Radioactive wastes/materials shall be managed according to Nigerian Nuclear	L	• SPDC Waste management plan • Waste consignment note • Reports • Site inspection Reports	Weekly	Project manager/DPR/FMEnv

Project activity	Description of Impacts	Impact Rating Before Mitigation	Mitigation Measures	Impact Rating After Mitigation	Parameter for Monitoring	Frequency of Monitoring	Responsible/ Action Party
			Regulatory Authority (NNRA) approved procedure. • SPDC waste management policy shall be enforced.				
	Increase in noise and vibration level	M	SPDC shall: • Use only pre-mobbed and regularly maintained equipment and water crafts	L	Premob certificates Maintenance records	Weekly	Project manager/DPR/FMEnv
	Loss of employment/ income	H	SPDC Shall: • Strengthen existing cooperation of the neighbouring communities via the existing Global Memorandum of Association interface. • Require contractors to prepare and implement workers disengagement plans • Encourage and support skill acquisition programmes of Government, NGOs and CBOs	L	• Evidences of workers disengagement plans, • Records of skill acquisition, • Evidence of support for micro-credits	Monthly	Project manager/DPR/FMEnv
	Risk of accident from vessel collision	H	SPDC shall ensure: • Adequate radio communication between offshore installations, merchant ships and standby vessels	L	• Journey management records • Premob certificates	As required	Project manager/DPR/FMEnv

Project activity	Description of Impacts	Impact Rating Before Mitigation	Mitigation Measures	Impact Rating After Mitigation	Parameter for Monitoring	Frequency of Monitoring	Responsible/ Action Party
			• Communication hardwares and agreed Global Maritime Distress and Safety System (GMDSS) procedures are effective • Regular drills on abandon ship procedures shall be enforced • Safety signages shall be deployed at strategic locations. • Activate Emergency response plan inline with SOLAS • Strict adherence to weather forcast information from the synoptic stations. • Only competent and experienced vessel crew with appropriate certification shall be used.		• Pep-talk records • Accident records		
	Risk of Piracy & kidnapping	H	SPDC shall: • Activate countermeasures to mitigate the threats of piracy and kidnapping. • Ensure project non productive time is reduced to the barest minimum. • All movements shall be undertaken only with	M	• Security Management procedure • Journey management procedure • Record of security	Monthly	Project manager/DPR/FMEnv

Project activity	Description of Impacts	Impact Rating Before Mitigation	Mitigation Measures	Impact Rating After Mitigation	Parameter for Monitoring	Frequency of Monitoring	Responsible/ Action Party
			Security Single Point Approval • All installation activities are executed under the supervision of a GSA armed escort.		situation/ updates • Site Inspection records		

Table 7.1f: Environmental Management Plan for the JK Exploration and Appraisal Wells Project - Commissioning

Project activity	Description of Impacts	Impact Rating Before Mitigation	Mitigation Measures	Impact Rating After Mitigation	Parameter for Monitoring	Frequency of Monitoring	Responsible/ Action Party
Commissioning	Increase in Business opportunities	P	SPDC shall ensure adherence to local content policy	P	• Employment records • Register of contractors • Contract Records	Quarterly	Project manager/DPR/FMEnv
	Air quality impairment from Well flare/vent	M	SPDC shall ensure limit flaring/venting to ALARP.	L	Records of gas flared	Quarterly	Project manager/DPR/FMEnv
	Risk of Piracy & kidnapping	H	SPDC shall: • Activate countermeasures to mitigate the threats of piracy and kidnapping. • Ensure project non productive time is reduced to the barest minimum. • All movements shall be undertaken only with	M	• Security Management procedure • Journey management procedure • Record of security situation/ updates	Monthly	Project manager/DPR/FMEnv

Project activity	Description of Impacts	Impact Rating Before Mitigation	Mitigation Measures	Impact Rating After Mitigation	Parameter for Monitoring	Frequency of Monitoring	Responsible/ Action Party
			Security Single Point Approval • All installation activities are executed under the supervision of a GSA armed escort.		• Site Inspection records		
	Risk of influx of Commercial Sex Workers to coastal communities with resultant increase in rates of Sexually Transmitted Infections	M	Community Health shall conduct sexual and reproductive health awareness campaigns.	L	• Health Awareness records	Annually	Project manager/DPR/FMEnv

Table 7.1g: Environmental Management Plan for the JK Exploration and Appraisal Wells Project - Operations and Maintenance

Project activity	Description of Impacts	Impact Rating Before Mitigation	Mitigation Measures	Impact Rating After Mitigation	Parameter for Monitoring	Frequency of Monitoring	Responsible/ Action Party
Operations and Maintenance	Improper disposal of materials removed from site	H	SPDC shall: • Ensure all oily wastes are properly segregated and contained before disposal. • Ensure all oily wastes are properly disposed of and monitored from cradle to grave. • Ensure regular clean-up of equipment at site.	L	• Waste consignment note • Site Inspection reports • Maintenance reports	Monthly	Project manager/DPR/FMEnv

Project activity	Description of Impacts	Impact Rating Before Mitigation	Mitigation Measures	Impact Rating After Mitigation	Parameter for Monitoring	Frequency of Monitoring	Responsible/ Action Party
			• Provide containment for chemicals and liquid discharges. • Ensure the enforcement of waste management policy. • Ensure that a controlled fuelling, maintenance and servicing protocol for machinery at worksite is established and followed to minimize leaks and spills. • Ensure Spent chemicals, lube oil, grease, waste oil and detergent solutions are properly disposed of. • Ensure used chemical drums and containers are sent to an approved recyclable waste dump (RWD). • Ensure that Small chemicals spills, crude oil and aqueous effluents shall be cleaned up promptly.				
	Equipment failure and damage leading to injuries/fatality	M	SPDC shall ensure that: • Only skilled personnel and certified equipment are used. • Certified first aiders shall be available at every site.	L	• Premob certificates • Maintenance records. • Certification of work force	Monthly	Project manager/DPR/FMEnv

Project activity	Description of Impacts	Impact Rating Before Mitigation	Mitigation Measures	Impact Rating After Mitigation	Parameter for Monitoring	Frequency of Monitoring	Responsible/ Action Party
			• First aid boxes and emergency response procedures are in place. • Hazard assessment has been conducted. • Emergency response procedures are in place. • HSE standards are strictly adhered to. • Permit to work and proper briefing is giving before any work can commence.		• First Aid box inventory • HAZID register • Records Tool box meeting • HSE inspection records. Emergency response procedure.		
	Air quality impairment from Well flare/vent	M	SPDC shall ensure limit flaring/venting to ALARP.	L	Records of gas flared	Quarterly	Project manager/DPR/FMEnv
	Risk of Piracy & kidnapping	H	SPDC shall: • Activate countermeasures to mitigate the threats of piracy and kidnapping. • Ensure project nonproductive time is reduced to the barest minimum. • All movements shall be undertaken only with Security Single Point Approval • All installation activities are executed under the supervision of a GSA armed escort.	M	• Security Management procedure • Journey management procedure • Record of security situation/ updates • Site Inspection records	Monthly	Project manager/DPR/FMEnv

Project activity	Description of Impacts	Impact Rating Before Mitigation	Mitigation Measures	Impact Rating After Mitigation	Parameter for Monitoring	Frequency of Monitoring	Responsible/ Action Party
	Leaks from process pipes, Well head equipment and flanges	M	SPDC shall: • Ensure adequate testing of pipes and values for leakages prior to introduction of hydrocarbon. • Installation of Emergency Shut down Valve (ESDV) to control excessive well pressure.	L	Site inspection report	Monthly	Project manager/DPR/FMEnv

Table 7.1h: Environmental Management Plan for the JK Exploration and Appraisal Wells Project - Decommissioning and Abandonment

Project activity	Description of Impacts	Impact Rating Before Mitigation	Mitigation Measures	Impact Rating After Mitigation	Parameter for Monitoring	Frequency of Monitoring	Responsible/ Action Party
Removal of surface installations Plugging of wells Site restoration	Increase in noise and vibration	M	SPDC shall • Use only pre-mobbed and regularly maintained equipment and water crafts	L	Premob certificates Maintenance records	Quarterly during decommissioning	Project manager/DPR/FMEnv
	Impairment of air quality from emission of HWR	M	SPDC shall: • Use only pre-mobbed crafts • Regular maintenance of water crafts, vessels, generators and other machines. • Use low sulphur containing fuel and low NOx burners	L	Premob certificates Maintenance records	Quarterly during decommissioning	Project manager/DPR/FMEnv
	Risk of Piracy & kidnapping	H	SPDC shall:	M	• Security Management procedure	Monthly	Project manager/DPR/FMEnv

Project activity	Description of Impacts	Impact Rating Before Mitigation	Mitigation Measures	Impact Rating After Mitigation	Parameter for Monitoring	Frequency of Monitoring	Responsible/ Action Party
			• Activate countermeasures to mitigate the threats of piracy and kidnapping. • Ensure project non-productive time is reduced to the barest minimum. • All movements shall be undertaken only with Security Single Point Approval • All installation activities are executed under the supervision of a GSA armed escort.		• Journey management procedure • Record of security situation/ updates Site Inspection records		
	Increase potential for water traffic accidents/ injury	M	SPDC shall ensure: • Adequate radio communication between offshore installations, merchant ships and standby vessels • Communication hardwares and agreed Global Maritime Distress and Safety System (GMDSS) procedures are effective • Regular drills on abandon ship procedures shall be enforced	L	• Journey management records • Pre-mob certificates • Pep-talk records • Accident records	Monthly during decommissioning activities	Project manager/DPR/FMEnv

Project activity	Description of Impacts	Impact Rating Before Mitigation	Mitigation Measures	Impact Rating After Mitigation	Parameter for Monitoring	Frequency of Monitoring	Responsible/ Action Party
			• Safety signages shall be deployed at strategic locations. • Activate Emergency response plan inline with SOLAS • Strict adherence to weather forcast information from the synoptic stations. • Only competent and experienced vessel crew with appropriate certification shall be used.				
	Potential for conflicts arising from labour issues	H	SPDC and her contractors shall: • Respond to complaints by locals on the activities of her workers. • Deploy GMOU provisions on community employment.	L	Records of employment	Quarterly during decommissioning	Project manager/DPR/FMEnv
	Injury/fatalities in workforce	H	SPDC shall ensure: • Daily pep talk is carried out for marine transportation • Safety signage shall be deployed at strategic locations. • Provide first aid boxes in operational water crafts. • Emergency response plan shall be in place.	L	• Certification of workforce • Emergency response plan • MSDS and Technical specification • HAZID register. • Pep-talk records	Monthly	Project manager/DPR/FMEnv

Project activity	Description of Impacts	Impact Rating Before Mitigation	Mitigation Measures	Impact Rating After Mitigation	Parameter for Monitoring	Frequency of Monitoring	Responsible/ Action Party
	Impairment of surface water and sediment quality from complete decommissioning activities	H	SPDC shall ensure that: • Effluents from decommissioning activities are treated to regulatory standards before discharge.	L	Site inspection report	Monthly	Project manager/DPR/FMEnv

Table 7.2: Environmental Monitoring Plan for the JK Exploration and Appraisal Wells Project

SOURCE OF IMPACT	ASSOCIATED LIMITATIONS		REGULATORY REQUIRED MONITORING PROGRAMME			
	Regulation/ Standard	Requirements/ Limits	Parameters to be monitored	Sampling Location	Frequency	Data Collection method
Sanitary wastewater	DPR EGASPIN II E 3.5.6.1(h) – Table II-6 Limitation on treated sanitary wastewater and DPR EGASPIN II E Table II-8	Maximum daily discharge rate Residual Cl-<1.5 mg/l BOD5< 45 mg/l Fecal coliform 400 MPN/100ml DO 4.0-5.0 mg/l	Daily rate Residual chlorine BOD5, Faecal coliform, MPN/100ml, DO	Discharge point from chlorinating unit (i.e. after treatment)	Weekly (apart from daily discharge rate)	Analysis of sample
Deck drainage	EGASPIN II E Table II-8	Monitor	Volume of deck drainage	Discharge point	Hourly when discharging	Estimate
			THC in deck drainage	Discharge point	Daily when discharging	Analysis of sample
Hydrocarbon release	DPR EGASPIN VIII B & C	Notification within 24 hours using Form A Report investigation finding within 1 week using Form B Report response/ clean up within 4 weeks using Form C	Oil Spill Contingency Response Readiness (procedures and plans at the rig site). Oil spill investigation and reporting			
Discharge of drilling waste (drilling fluids, cuttings, sand)	DPR EGASPIN II E 3.5.4.2 (Discharge of toxic substances during drilling)	Daily minimum and monthly average 96hrLC50 of 30,000 ppm for Palaemonetes africanus in 9:1 seawater to drilling fluid suspended particulate phase Maximum discharge rate of 1,000 bbls/hr EXCEPT drilling fluid discharges that are shunted to the bottom	96 Hr LC50 for drilling fluid and drill cuttings Discharge rate		Once a month and at end of well drilling	Laboratory analysis
	DPR EGASPIN II E 3.5.6.1 and DPR EGASPIN II E Table II-8 MARPOL 93/98	No discharge into inland or nearshore waters No visible oil sheen for WBM No more than 5% oil on cuttings for SBM No more than 1% oil on cuttings for LTOBM No more than 10 g of oil on Kg (dry weight) of solid pH Metals Petroleum Hydrocarbons	Oil on cuttings pH Metals Petroleum Hydrocarbons Total hydrocarbons PAH	Every 305 m From the lowest section of well (NOT in pay zone)	Every 305 m	Sampling of treated drill cuttings and analyses of samples to be carried out by a DPR-accredited laboratories.
	DPR EGASPIN II E Table II-8	Monitoring	Free oil	Surrounding waters	Weekly during discharge	Visual check
			THC in drilling fluid	Every 305 m	Every 305 m	Laboratory analysis

Table 7.2: Environmental Monitoring Plan for the JK Exploration and Appraisal Wells Project

SOURCE OF IMPACT	ASSOCIATED LIMITATIONS		REGULATORY REQUIRED MONITORING PROGRAMME			
	Regulation/ Standard	Requirements/ Limits	Parameters to be monitored	Sampling Location	Frequency	Data Collection method
				From the lowest section of well (NOT in pay zone)		
	DPR EGASPIN II E 3.5.6.2 (g) & DPR EGASPIN Appendix II-4	Post-drill Environmental Seabed Survey	THC, TPH/PAH, particle size, major & trace metals, benthic organisms	100, 200, 500, 800, 1,200, 2,500 & 5,000m from well + 3 clean stations	One off. (After 5 wells OR 9 months after drilling)	Seabed and water column sampling and analysis and in-situ measurements
Other liquid waste (waste oils, paint, chemicals, BOP, well treatment and work over fluids)	DPR EGASPIN VIII C	Categorise and quantify waste	Categorisation of waste and management from cradle to grave	Waste discharge points	Continuous	Record quantity in each category of waste
	DPR EGASPIN II E Table II-8	Monitor specified parameters	Volume of BOP fluid	Discharge point	Hourly during discharge	Measure/Estimate
			Volume of well treatment and	Discharge point	Daily during discharge	Meter OR estimate
Other liquid waste (waste oils, paint, chemicals, BOP, well treatment and work over fluids) cont'd	DPR EGASPIN II E Table II-8 cont'd	Monitor specified parameters cont'd	Volume, pH, Chloride and THC for work over fluids and wastes	Discharge point	Daily during discharge	In-situ measurements AND/OR Laboratory analysis
			Hg & Cd	Mud	1ce per new stock of barite/ new well	Laboratory analysis
Well drilling casing and well completion	DPR EGASPIN II E 3.5.6.2 (g)	Post drill survey after every 5 wells OR after 9 months	For sediment: TPH, PAH, Particle size, TOC, Redox Potential, Major & Trace metals, Benthic macrofauna For ocean water: THC, Major & Trace metals	100m; 200m; 500m; 800m; 1,200m; 2,500m; and 5,000m from each well	After every 5 wells OR 9 months after drilling	In-situ measurements and Laboratory analysis
Combustion	DPR EGASPIN III E 4.4.2 Gaseous point sources emission monitoring	1-hour mean (µg/m3) CO(3) =30 SO2 = 350; NO2(3) = 400; Total SPM = 150- 230	Volume of fuel/gas consumed Emissions rate CO, CO2, SOx, NOx, THC, VOC, SPM from emissions	Emission point	Continuous readings – record daily	Normal operations flow meter is read daily.
	DPR EGASPIN III E 4.4.5 Table III-3 National Ambient Air Quality Standards	Daily average mean (µg/m3) (3) CO =10 SO2 = 100-150 NO2(3) = 150 Total SPM = 60-90	Particulates, ozone, H2S, heavy and trace metals in ambient air	Emission point	Weekly (DPR) Monthly (TBC)	Calculate using emission factors for fuel consumed
Fugitive (hydrocarbon) emissions	Internal SIEP requirements	SIEP requirements	VOC		Quarterly	Estimated using component emission factors or use Empirical model based upon

Table 7.2: Environmental Monitoring Plan for the JK Exploration and Appraisal Wells Project

SOURCE OF IMPACT	ASSOCIATED LIMITATIONS		REGULATORY REQUIRED MONITORING PROGRAMME			
	Regulation/ Standard	Requirements/ Limits	Parameters to be monitored	Sampling Location	Frequency	Data Collection method
						hydrocarbon throughput

CHAPTER EIGHT
CONCLUSION

The Environmental Impact Assessment Studies of the JK Exploration and Appraisal Wells Project was conducted in accordance with relevant local, national and international regulations and guidelines. The methodology applied for the study involved a two-season field work, laboratory analyses and extensive stakeholder's engagement exercise. To achieve this objective, a multi-disciplinary approach was adopted in the assessment of the environmental status and sensitivities of the various biophysical, social and health profile of coastal communities. The JK Exploration and Appraisal Wells Project provides an opportunity to appraise the discovered oil and gas resources and explore for new hydrocarbon resources (HC) in the JK field. The well discovered in-place volume of 201 MMSTB and 52 Bscf. This opportunity will boost the Federal Government and SPDC's oil and gas production targets, increase foreign exchange earnings and develop in-country capacity. Other positive impacts of the proposed project include but not limited to the following: increase in business opportunities and Opportunity for contracting.

Furthermore, the baseline data revealed the high carrying capacity of the aquatic ecosystem, rich biodiversity resources and near pristine airshed within the project area. The social and health profile of coastal communities revealed high expectations with regards to employment opportunities, scholarships and social investments.

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 1

Federal Ministry of Environment Terms of Reference Approval

FEDERAL MINISTRY OF ENVIRONMENT

Environment House

Independence Way South, Central Business District, Abuja - FCT.
Tel: 09-2911 337 www.environment.gov.ng, ea-environment.org

ENVIRONMENTAL ASSESSMENT DEPARTMENT

Ref: FMENV/EA/EIA/4720/T/15
Date: 17th August, 2018

The Managing Director,
The Shell Petroleum Development Company of Nigeria Limited,
Freeman House,
21/22 Marina House,
P.M.B. 2418
Lagos.

RE: SUBMISSION OF TERMS OF REFERENCE FOR THE JK EXLPORATION AND APPRAISAL WELLS PROJECT AND REQUEST FOR A NOMINEE FOR THE FIELD DATA GATHERING EXERCISE

Please refer to your letter ref: SPDC-HSE-2018-02791 dated 23rd May, 2018 on the above subject.

2. I am directed to acknowledge the receipt of the scoping workshop report submitted to the Ministry and to inform you that the project ToR is approved subject to the following conditions;

i. SPDC shall incorporate all concerns expressed by the stakeholders during the scoping workshop.

ii. SPDC shall address environmental and social issues that would emerge throughout the project phases

3. Thank you for your co-operation.

Received.
Time
20 AUG 2018
Signature
SHELL OFFICE ABUJA

Abbas O. Suleiman
For. Honourable Minister

Department of Petroleum Resources ToR/SoW Approval

MINISTRY OF PETROLEUM RESOURCES

DEPARTMENT OF PETROLEUM RESOURCES

7, KOFO ABAYOMI STREET, VICTOTIA ISLAND, LAGOS

P.M.B. No: 12650

Telephone: 01-2790000

Website: www.dpr.gov.ng

Ref. No: DPR/HSE.02/001.102/2018/040

Date: 19th July 2018

The Managing Director
Shell Petroleum Development Company (Nig.) Limited
Freeman House
21/22 Marina
Lagos

SPDC
RECEIVED
24 JUL 2018
TIME 14:37 HRS

Dear Sir,

APPROVAL OF TERMS OF REFERENCE (TOR) / SCOPE OF WORK (SOW) FOR THE ENVIRONMENTAL IMPACT ASSESSMENT (EIA) OF JK EXPLORATORY AND APPRAISAL WELLS PROJECT

We refer to your letter of July 5, 2018 referenced SPDC-HSE-2018-0347L transmitting the TOR/SOW for the Environmental Impact Assessment (EIA) of JK Exploratory Wells Project.

2. We have reviewed the submitted TOR/SOW for the EIA and noted that it has met our minimum requirements. Consequently, we are pleased to convey to you the Department's acceptance and approval of the TOR/SOW.

3. The field data gathering for the study shall be for two seasons (wet and dry) and the collected samples shall be analysed for the following parameters:

S/N	Sample	Analysis	Parameters	Remarks
1.	Sediment 96 + 3 controls	Physico-chemical	Colour, particle size, temperature, pH, salinity, THC, TPH, TOC, exchangeable cations (Na, K, Ca and Mg), Available PO_4^{3-}, NH_4^+, NO_3^-, BTEX, redox potential, Oil & grease, heavy metals (Fe, Cd, Cr, Pb, Cu, Ba, Ni, V, Ag, Co and Zn), etc.	Sediment samples for BTEX shall be collected in glass bottles preserved in methanol. GC with a purge & trap system or GC-FID with headspace shall be used for the analysis

				of BTEX. Samples for PAH analysis shall be conducted with a GC-MS. Oil & grease/TPH shall be analysed using infrared spectrophotometer. Control samples shall be collected from pristine environments.
		Microbiology	THB, THF, THUB, THUF, SRB and Fecal Coliform	
		Macro benthos	Benthic macro-invertebrate studies – identification to the nearest taxonomic level as well as their species distribution, abundance, dominance, diversity and density, etc.	Different statistical tools such as Margalef index, Shannon's index, Evenness index and dendrogram shall be employed to make reasonable inferences.
2.	**Surface water 96 + 3 controls**	Physico-chemical	Colour, Temperature, pH, DO, salinity, conductivity, depth and width, flow direction and flow rate, alkalinity, BTEX, TPH, TDS, TSS, Turbidity, THC, pH, DO, BOD_5, COD, anions/cations, NH_4^+, NO_3^-, NO_2^-, PO_4^{3-}, SO_4^{2-}, SiO_2^-, Na, K, Ca, Mn, Mg, Heavy metals (Fe, Cd, Cr, Ni, V, Pb, Zn, Ba, Hg), etc.	Samples for BTEX samples shall be taken with vials. Analyses for BTEX, PAH, THC/Oil & grease shall be as stated above. Water profiling shall be done with a CTD profiler.
		Microbiology	THB, THF, THUB, THUF, SRB and faecal coliforms	
		Hydrobiology (Phytoplankton)	Identification to the nearest taxonomic level, Species diversity (composition, distribution and density) and productivity (chlorophyll concentration)	Same as macro benthos above.
		Hydrobiology (Zooplankton)	Identification to the nearest taxonomic level, species diversity	-do-

			(composition, distribution and density)	
		Fisheries	Species types, species diversity, fish spawning area, fish catch where possible, food & feeding habits, fish stock assessment, fish migration pattern, breeding habits, presence of protected species, fish spawning area, distribution catch assessment survey (CAS), breeding sites, migration routes and fishery activities.	Histological studies, fecundity, gonad ratio, etc. shall be reported as part of this study.
		Hydrodynamics	Water depth and width, flow direction and flow rate.	
3.	**Air Quality/Noise** **(24 + 3 Controls)**	Ambient	VOCs, SO_2, NO_2, CH_4, CO, CO_2, temperature, Noise Levels, SPM, PM2.5, PM10, wind speed and direction.	One (1) hour mean for each of the air quality parameters shall be taken per station. A total of four (4) data sets should be collected within 1 hr.
4.	**Social & Health Impact Assessment**		Vital health statistics, disease prevalence, predisposing factors, existing health institutions/facilities in the area, identification of communities in the study area, social organisations/institutions, population distribution & density, birth rate, land use, water use, life expectancy, employment status, archaeological sites, cultural and religious practices, restricted areas, occupation, etc.	The Coastal Communities within 1 km of the JK field should be studied.

4. Please note that you are required to use statistical analysis (mean, standard deviation, ANOVA, etc.) to present your results and make necessary trend analysis with previous results from other proximal fields if available.

5. On conclusion of this study, you are to submit two separate draft reports, an EIA for the FOD studies and the EE/BM studies in both electronic (compact disc) and hard copy to the DPR for review and approval. The electronic copy should also include a stand- alone environmental dataset (physico–chemical and biological parameters) in Excel format covering all relevant environmental aspects in the study.

6. Finally, you are required to liaise with this Office in good time to ensure our adequate participation in the field data gathering exercise and subsequent laboratory analyses.

Yours faithfully,

Abdurrahman A. S.
for: Director, Petroleum Resources

Appendix 2
Coordinate listing

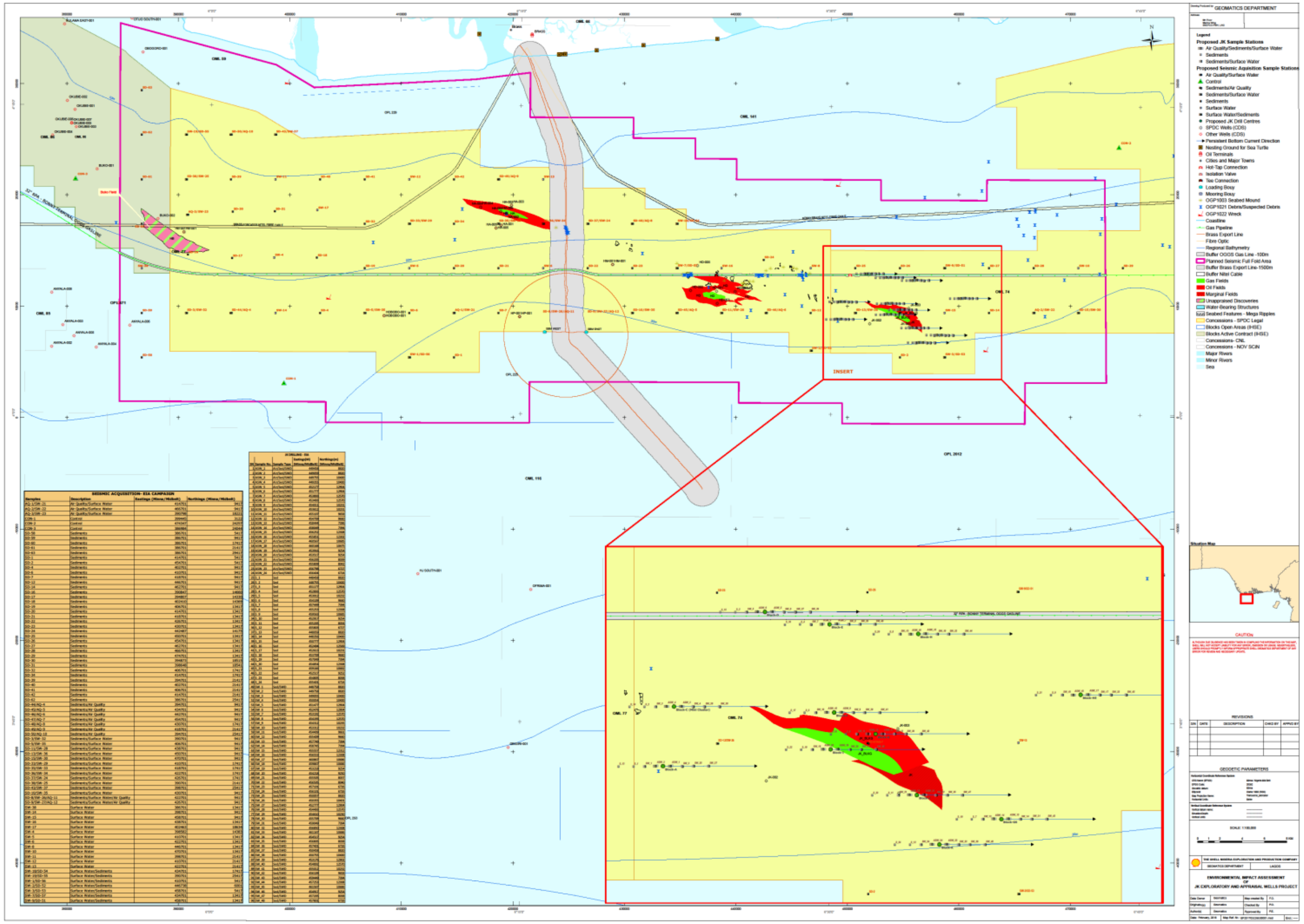
JK DRILLING - EIA				
SN	Sample No.	Sample Type	Eastings(M) (Minna/MidBelt)	Northings(m) (Minna/MidBelt)
1	ASW_1	Air/Sed/SWD	449458	8820
2	ASW_2	Air/Sed/SWD	449059	8820
3	ASW_3	Air/Sed/SWD	449755	10400
4	ASW_4	Air/Sed/SWD	449355	10400
5	ASW_5	Air/Sed/SWD	452177	12904
6	ASW_6	Air/Sed/SWD	451777	12904
7	ASW_7	Air/Sed/SWD	453893	12570
8	ASW_8	Air/Sed/SWD	453493	12570
9	ASW_9	Air/Sed/SWD	454011	10231
10	ASW_10	Air/Sed/SWD	453612	10231
11	ASW_11	Air/Sed/SWD	455107	9658
12	ASW_12	Air/Sed/SWD	454709	9660
13	ASW_13	Air/Sed/SWD	458444	7396
14	ASW_14	Air/Sed/SWD	458049	7394
15	ASW_15	Air/Sed/SWD	456252	12308
16	ASW_16	Air/Sed/SWD	455851	12302
17	ASW_17	Air/Sed/SWD	460567	10685
18	ASW_18	Air/Sed/SWD	460168	10675
19	ASW_19	Air/Sed/SWD	453916	9254
20	ASW_20	Air/Sed/SWD	453517	9254
21	ASW_21	Air/Sed/SWD	456205	8039
22	ASW_22	Air/Sed/SWD	455809	8042
23	ASW_23	Air/Sed/SWD	456798	6727
24	ASW_24	Air/Sed/SWD	456404	6724

25	S_1	Sed	448458	8820
26	S_2	Sed	448755	10400
27	S_3	Sed	451177	12904
28	S_4	Sed	452893	12570
29	S_5	Sed	453012	10232
30	S_6	Sed	454109	9660
31	S_7	Sed	457449	7394
32	S_8	Sed	455253	12308
33	S_9	Sed	459563	10685
34	S_10	Sed	452917	9254
35	S_11	Sed	455205	8034
36	S_12	Sed	455803	6727
37	S_13	Sed	448059	8820
38	S_14	Sed	448356	10400
39	S_15	Sed	450777	12904
40	S_16	Sed	452494	12569
41	S_17	Sed	452613	10231
42	S_18	Sed	453709	9660
43	S_19	Sed	457049	7394
44	S_20	Sed	454854	12308
45	S_21	Sed	459166	10682
46	S_22	Sed	452517	9252
47	S_23	Sed	454805	8038
48	S_24	Sed	455401	6724

49	SW_1	Sed/SWD	448758	8820
50	SW_2	Sed/SWD	449758	8820
51	SW_3	Sed/SWD	449055	10400
52	SW_4	Sed/SWD	450054	10400
53	SW_5	Sed/SWD	451477	12904
54	SW_6	Sed/SWD	452476	12904
55	SW_7	Sed/SWD	453192	12570
56	SW_8	Sed/SWD	454193	12570
57	SW_9	Sed/SWD	454312	10235
58	SW_10	Sed/SWD	453312	10232
59	SW_11	Sed/SWD	454409	9661
60	SW_12	Sed/SWD	455409	9660
61	SW_13	Sed/SWD	457749	7394
62	SW_14	Sed/SWD	458745	7394
63	SW_15	Sed/SWD	455557	12312
64	SW_16	Sed/SWD	456553	12308
65	SW_17	Sed/SWD	460867	10686
66	SW_18	Sed/SWD	459867	10686
67	SW_19	Sed/SWD	453218	9254
68	SW_20	Sed/SWD	454218	9250
69	SW_21	Sed/SWD	455505	8037
70	SW_22	Sed/SWD	456505	8040
71	SW_23	Sed/SWD	457101	6726
72	SW_24	Sed/SWD	456101	6726

73	SW_25	Sed/SWD	450057	8820
74	SW_26	Sed/SWD	450355	10401
75	SW_27	Sed/SWD	452777	12904
76	SW_28	Sed/SWD	454493	12570
77	SW_29	Sed/SWD	454610	10230
78	SW_30	Sed/SWD	455709	9660
79	SW_31	Sed/SWD	459049	7394
80	SW_32	Sed/SWD	456850	12308
81	SW_33	Sed/SWD	461167	10686
82	SW_34	Sed/SWD	454517	9254
83	SW_35	Sed/SWD	456805	8038
84	SW_36	Sed/SWD	457401	6726
85	SW_37	Sed/SWD	450458	8820
86	SW_38	Sed/SWD	450755	10400
87	SW_39	Sed/SWD	453176	12902
88	SW_40	Sed/SWD	454892	12570
89	SW_41	Sed/SWD	455012	10232
90	SW_42	Sed/SWD	456109	9658
91	SW_43	Sed/SWD	459449	7394
92	SW_44	Sed/SWD	457253	12308
93	SW_45	Sed/SWD	461567	10686
94	SW_46	Sed/SWD	454917	9254
95	SW_47	Sed/SWD	457205	8038
96	SW_48	Sed/SWD	457801	6726

Appendix 3
Sampling Map



Appendix 5
Attendance sheet – Scoping workshop

ENVIRONMENTAL IMPACT ASSESSMENT SCOPING/ STAKEHOLDERS' ENGAGEMENT WORKSHOP FOR OML 77/74 SEISMIC DATA ACQUSITION/JK EXPLORATORY AND APPRAISAL WELLS PROJECTS

ATTENDANCE REGISTER, Wednesday, 18th April, 2018

S/No	Name	Community / Affiliation	Signature
1	Okeke Iduboden [illegible]	Federal Ministry of Environment	[signature]
2	Angoule - O. Angoule	BYMBAY	[signature]
3	Ogbe E-Elliot	BYMENY.	[signature]
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ENVIRONMENTAL IMPACT ASSESSMENT SCOPING/ STAKEHOLDERS' ENGAGEMENT WORKSHOP FOR OML 77/74 SEISMIC DATA ACQUSITION/JK EXPLORATORY AND APPRAISAL WELLS PROJECTS

ATTENDANCE REGISTER, Wednesday, 18th April, 2018

S/No	Name	Community / Affiliation	Signature
1	HRH KING FRANCIS MENE-DAULAGHA	IBIDI	18-04-2018
2	[illegible] Wayte	CHEF	17-04-2018
3	OTOKOLO AYEBANUMOMOPIAKE	C D C CHIRMAN	
4	OMIETIMI CLEVER	IBIDI / PRESIDENT	
5	Deborah Mene	Ibidi / women Leader	
6	HH Golden William-Smith	THOM BRASS KINGDOM	
7	Chf Moses I.F Iyafa	✓ ✓ ✓	
8	Olulo Inatimi	✓ ✓ ✓	
9	Aboh Ebiegberi R.	✓ ✓ ✓	
10	Mrs Douglas Doris	✓ ✓ ✓	
11	Chf Ingha-Spiff Inikio	Palm Mbikiri	
12	CHF MOSES KAKAIN	PALM IMBIKIRI	
13	Mr. George Melem	PALM IMBIKIRI	
14	Talbert Emmanuel	PALM IMBIKIRI	
15	Andrew Karina	PALM IMBIKIRI	

ENVIRONMENTAL IMPACT ASSESSMENT SCOPING/ STAKEHOLDERS' ENGAGEMENT WORKSHOP FOR OML 77/74 SEISMIC DATA ACQUSITION/JK EXPLORATORY AND APPRAISAL WELLS PROJECTS

ATTENDANCE REGISTER, Wednesday, 18th April, 2018

S/No	Name	Community / Affiliation	Signature
1	HRH KING FRANCIS MENE-DAULAGHA	IBIDI	[illegible] 18-04-2018
2	[illegible] Wayte	CHIEF	[illegible] 17-04-2018
3	OTOKOLO AYEBANUMOMOPIRE	CDC CHAIRMAN	[illegible]
4	OMIETIMI CLEVER	IBIDI / PRESIDENT	[illegible]
5	Deborah Mene	Ibidi / Women Leader	[illegible]
6	HH Golden William-Smith	TWON BRASS KINGDOM	[illegible]
7	Chf Moses I.F Iyafa	✓ ✓ ✓	[illegible]
8	Olole Inatimi	✓ ✓ ✓	[illegible]
9	Aboh Ebiegberi R.	✓ ✓ ✓	[illegible]
10	Mrs Douglas Doris	✓ ✓ ✓	[illegible]
11	Chf Ingha-Spiff Iniku	Palm Mbikiri	[illegible]
12	CHF MOSES KAKAIN	PALM IMBIKIRI	[illegible]
13	Mr. George Nelem	PALM IMBIKIRI	[illegible]
14	Talbert Emmanuel	PALM IMBIKIRI	[illegible]
15	Andrew Kamina	PALM IMBIKIRI	[illegible]

ENVIRONMENTAL IMPACT ASSESSMENT SCOPING/ STAKEHOLDERS' ENGAGEMENT WORKSHOP FOR OML 77/74 SEISMIC DATA ACQUSITION/JK EXPLORATORY AND APPRAISAL WELLS PROJECTS

ATTENDANCE REGISTER, Wednesday, 18th April, 2018

S/No	Name	Community / Affiliation	Signature
1	Chief ThankGod E-Seriyai	Odioama, HRH Reps	
2	Chief Innocent L-Nagha	Odioama, Chief	
3	Hon. Philemon K. Dickson	Odioama, CDC	
4	Mr Forcebray I. Ekelekpe	Odioama, Youth President	
5	Mdm Boumokuma Sample	Odioama, Women Leader	
6	Ch. Dickson Iboomo	Egbabele Com. Chief	
7	Mr Lyon K. Gbalipre	Igbabe	
8	Boumowei David	✓	
9	FRANK EKPARA	✓	
10	LYON INAINGO.K.	✓ IGBABELEU	
11	Chief (Hon) B N Amamo-Ikpikpi	Beletiema HRH	
12	Chief Kaiidigha Isaac	✓	
13	Madam Ayerite Otuturu	✓ women leader	
14	Mr Betimi Brown	✓ CDC	
15	Joel Kilison	Beletiema Youth leader	

ENVIRONMENTAL IMPACT ASSESSMENT SCOPING/ STAKEHOLDERS' ENGAGEMENT WORKSHOP FOR OML 77/74 SEISMIC DATA ACQUSITION/JK EXPLORATORY AND APPRAISAL WELLS PROJECTS

ATTENDANCE REGISTER, Wednesday, 18th April, 2018

S/No	Name	Community / Affiliation	Signature
1	Chief ThankGod E-Serigai	Odioama, HRH Reps	[signature]
2	Chief Innocent L-Nagha	Odioama, Chief	[signature]
3	Hon. Philemon K. Dickson	Odioama, CDC	[signature]
4	Mr Forcebray E. Ekelekpe	Odioama, Youth President	[signature]
5	Mdm Boumokuma Sample	Odioama, Women Leader	[signature]
6	Ch. Dickson Idomo	Egbabele Com. Chief	[signature]
7	Mr Lyon K. Gbalupa	Igbabe	[signature]
8	Boumowei David	✓	[signature]
9	FRANK EKPARA	✓	[signature]
10	LYON INAINGO.K.	✓ IGBABELEU	[signature]
11	Chief (Hon) B N Amamo-Ikpikpi	Beletiema HRH	[signature]
12	Chief Kaikdigha Isaac	✓	[signature]
13	Madam Ayerite Otutunu	✓ women leader	[signature]
14	Mr Betimi Biowon	✓ CDC	[signature]
15	Joel Kilison	Beletiema Youth leader	[signature]

ENVIRONMENTAL IMPACT ASSESSMENT SCOPING/STAKEHOLDER'S ENGAGEMENT WORKSHOP FOR OML 77/74 SEISMIC DATA ACQUISITION/JK EXPLORATORY AND APPRAISAL WELLS PROJECTS

ATTENDANCE REGISTER, Tuesday, 24th April, 2018

S/No	Name	Community/Affiliation	Signature
1	Onyeagba Deborah C.	Pro Nature International (PNI)	[signature]
2	Emmanuel I. Oye	R/S Ministry of Environment	[signature]
3	Nimi Elele	R/S Min of Environment	[signature]
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ENVIRONMENTAL IMPACT ASSESSMENT SCOPING/STAKEHOLDER'S ENGAGEMENT WORKSHOP FOR OML 77/74 SEISMIC DATA ACQUISITION/JK EXPLORATORY AND APPRAISAL WELLS PROJECTS

ATTENDANCE REGISTER, Tuesday, 24th April, 2018

S/No	Name	Community/Affiliation	Signature
1	CHF. TAMUNOKURO AMAKIRI	(ANGAEABIO AMA)	
2	CHF. MARK TARIAH	✓	
3	ALABOTA MERA ODUTE	WOMAN LEADER	
4	ELDER OTUMBA LAWSON	CDC CHAIRMAN	
5	ELDER MACGTORI. BUBNANE	YOUTH LEADER	
6	CHF COMR MINABIYE LAW DOUPAN	PARAMOUNT RULER (ABAJIOKALO)	
7	CHF TONYE EREKEOSIMA	CHIEF IN COUNCIL (A ✓	
8	MR DIMABO MACWILLIAM	CHAIRMAN C.D.C ✓	
9	MR SOMINA B.T. WEST	YOUTH LEADER ✓	
10	MRS PRESCILLA DONPEDRO A.	WOMAN LEADER ✓	
11			
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14			
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Appendix 6
Chain of Custody for Analytical samples

ENVIRONMENTAL AND LABORATORY SERVICES	Document Number ELS-FRM-350024
INTERNATIONAL ENERGY SERVICES LIMITED	Revision: 02 — Status: IFA
	Rev. Date: 16/DEC/2011
	Page 1 of 3

CHAIN OF CUSTODY RECORD

Project Title/No: JK EXPLORATION & APPRAISAL WELLS PROJECT

Client Name: SPDC

Client Project No.: IES-ELS-SPDC JK EXPLORATION- 18 0920/9-020078

Collection Site: JK DRILLING

No. of Samples: 153 WATER SAMPLES

Comments:

Turn Around Time: ☐ Standard ☐ Day(s) ☐ Week ☐ Month(s)

Container Type: M=Metal; G=Glass; P=Plastic

Delivered by (Name/Sign.): KORDAH ERIC Date: 18/9/2019 Time ____

Received by (Name/Sign.): Kama Uhioma Date: 18/9/2019 Time ____

Delivery Method: ☑ In Person ☐ Laboratory ☐ Courier Service ☐ Others (Specify)

Sample ID	Sampling Depth	Sampling date	Date Arrived Lab	Container			Sample Type			Preserv. (Ice, HCl, HNO_3, H_2SO_4, others)	Field Analysis						Analysis Required
				No.	Type	Sample Size	Soil/ Sediment	Water/ Crude	Sludge		Temp	pH	EC (mS)	Turb	DO	TDS	
SW45	TOP	07/09/2019		1	P	1 Ltr		✓		ICE	28.1	8.21	27150	0.0	5.8	13580	PC
				1	P	120 ml		✓		HNO_3							HM
				1	G	250 ml		✓		HCL							O/G
				1	G	250 ml		✓		ICE							BOD
SW 45	MID	9/9/19		1	P	1 Ltr		✓		ICE	27.6	8.30	34600	0.0	4.4	17300	PC
				1	P	120 ml		✓		HNO_3							HM
				1	G	250 ml		✓		HCL							O/G
				1	G	250 ml		✓		ICE							BOD
SW 45	BOT	9/9/19		1	P	1 Ltr		✓		ICE	26.4	8.40	43400	0.0	3.9	30380	PC
				1	P	120 ml		✓		HNO_3							HM
				1	G	250 ml		✓		HCL							O/G
				1	G	250 ml		✓		ICE							BOD
SW 33	TOP	9/9/19		1	P	1 Ltr		✓		ICE	28.8	8.59	31700	0.0	6.0	15900	PC
				1	P	120 ml		✓		HNO_3							HM
				1	G	250 ml		✓		HCL							O/G
				1	G	250 ml		✓		ICE							BOD

Chain of Custody Record

ADESOLA OJESANMI 9/9/19 — OYEBODE TAOFEEK FMEnv 9/9/19 — OZUGU, FRED T. 9/9/19 SYMENV. — Ucheokoro, U. 9/9/19 DPR

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	ENVIRONMENTAL AND LABORATORY SERVICES	Document Number ELS-FRM-350024
		Revision: 02 / Status: IFA
	INTERNATIONAL ENERGY SERVICES LIMITED	Rev. Date: 16/DEC/2011
		Page 1 of 3

CHAIN OF CUSTODY RECORD

Project Title/No: JK EXPLORATION & APPRAISAL WELLS PROJECT

Client Name: SPDC

Client Project No: IES-ELS-SPDC JK EXPLORATION-18092019-020278

Collection Site: JK DRILLING

No. of Samples: 153 WATER SAMPLES

Comments:

Turn Around Time: ☐ Standard ☐ Day(s) ☐ Week ☐ Month(s)

Container Type: M=Metal; G=Glass; P=Plastic

Delivered by (Name/Sign.): KORDATT ERIC Date: 18/9/2019 Time

Received by (Name/Sign.) Kama Uhiomg Date 18/9/2019 Time

Delivery Method: ☑ In Person ☐ Laboratory ☐ Courier Service ☐ Others (Specify)

Sample ID	Sampling Depth	Sampling date	Date Arrived Lab	Container No.	Container Type	Sample Size	Sample Type: Soil Sediment	Water/ Crude	Sludge	Preserv. (Ice, HCl, HNO_3, H_2SO_4, others)	Temp	pH	EC (mS)	Turb	DO	TDS	Analysis Required
SW45	TOP	07/09/2019		1	P	1Ltr		✓		ICE	28.1	8.21	27150	0.0	5.8	13580	PC
				1	P	120 ml		✓		HNO_3							HM
				1	G	250 ml		✓		HCL							O/G
				1	G	250 ml		✓		ICE							BOD
SW 45	MID	9/9/19		1	P	1Ltr		✓		ICE	27.6	8.30	34600	0.0	4.4	17300	PC
				1	P	120ml		✓		HNO_3							HM
				1	G	250ml		✓		HCL							O/G
				1	G	250ml		✓		ICE							BOD
SW 45	BOT	9/9/19		1	P	1Ltr		✓		ICE	26.4	8.40	43400	0.0	3.9	30380	PC
				1	P	120ml		✓		HNO_3							HM
				1	G	250ml		✓		HCL							O/G
				1	G	250 ml		✓		ICE							BOD
SW 33	TOP	9/9/19		1	P	1Ltr		✓		ICE	28.8	8.59	31700	0.0	6.0	15900	PC
				1	P	120 ml		✓		HNO_3							HM
				1	G	250 ml		✓		HCL							O/G
				1	G	250 ml		✓		ICE							BOD

Chain of Custody Record

ADESOYE Ojeyemmi 9/9/19

OYEBODE TAOFEEK FMENV 9/9/19

OZUGU, FRED T. 9/9/19 SYMENV.

Ucheokoro, U. 9/9/19 DPR

1

ISL	ENVIRONMENTAL AND LABORATORY SERVICES	Document Number ELS-FRM-350024
		Revision: 02 — Status: IFA
	INTERNATIONAL ENERGY SERVICES LIMITED	Rev. Date: 16/DEC/2011
		Page:1 of 3

CHAIN OF CUSTODY RECORD

Project Title/No: JK EXPLORATION & APPRAISAL WELLS PROJECT.
Client Name: SPDC
Client Project No: IES-ELS-SPDC JK EXPLORATION-18092019-020078
Collection Site: JK DRILLING
No. of Samples: 99 SEDIMENT SAMPLES

Comments:

Turn Around Time: ☐ Standard ☐ Day(s) ☐ Week ☐ Month(s)

Container Type: M=Metal; G=Glass; P=Plastic

Delivered by (Name/Sign.): KOROATT ERIC Date: 18/9/2019 Time
Received by (Name/Sign.): Kama Ujuoma Date 18/9/2019 Time

Delivery Method: ☐ In Person ☐ Laboratory. ☐ Courier Service ☐ Others (Specify)

	Sample ID	Sampling Depth (m)	Sampling date	Date Arrived Lab	Container No.	Container Type	Sample Size	Sample Type Soil/Sediment	Sample Type Water/Crude	Sample Type Sludge	Preserv. (ice, HCl, HNO_3, H_2SO_4, others)	Field Analysis ~~Temp~~ REDOX	pH	EC (mS)	Turb	DO	TDS	Analysis Required
(SED 45)	SW45	33	9/9/19		1		SED	SEDIMENT			ICE	-23.6	7.42					
(SED 33)	SW33	33	✓		1			✓			✓	-30.4	7.63					
(SED 17)	SW17	33	✓		1			✓			✓	-31.6	7.68					
	ASW17	33	✓		1			✓			✓	-33.8	7.74					
	ASW18	32	✓		1			✓			✓	-33.8	7.69					
	S9	32	✓		1			✓			✓	-22.9	7.37					
	SW18	32	✓		1			✓			✓	-33.9	7.71					
	S21	32	✓		1			✓			✓	-31.6	7.58					
	SW44	29	✓		1			✓			✓	-31.9	7.60					
	SW32	29	✓		1			✓			✓	-23.9	7.36					
	SW16	29	10/9/19		1			✓			✓	-24.3	7.27					
	SW47	36	✓		1			✓			✓	-48.9	7.76					
	SW35	36	✓		1			✓			✓	-52.4	7.84					
	SW22	36			1			✓			✓	-46.1	7.72					
	ASW21	36			1			✓			✓	-45.6	7.70					

Chain of Custody Record

ADESOLA OFESOMM
SPDC 10/9/19

OYEBODE TAOFEEK
FMENV 10/9/19

OZEGU, FRED T
10/9/19
BY FMENV.

Udeakara, U.
10/9/19
DPR

ENVIRONMENTAL AND LABORATORY SERVICES

INTERNATIONAL ENERGY SERVICES LIMITED

Document Number ELS-FRM-350024
Revision: 02 | Status: IFA
Rev. Date: 16/DEC/2011
Page:1 of 3

CHAIN OF CUSTODY RECORD

Project Title/No: JK EXPLORATION & APPRAISAL WELLS PROJECT.
Client Name: SPDC
Client Project No: IES-ELS-SPDC JK EXPLORATION-18092019-020078
Collection Site: JK DRILLING
No. of Samples: 99 SEDIMENT SAMPLES

Comments:

Turn Around Time: ☐ Standard ☐ Day(s) ☐ Week ☐ Month(s)

Container Type: M=Metal; G=Glass; P=Plastic

Delivered by (Name/Sign.): KORO-ATT ERIC Date: 18/9/2019 Time____
Received by (Name/Sign.): Kama Ujuoma Date 18/9/2019 Time____

Delivery Method: ☐ In Person ☐ Laboratory. ☐ Courier Service ☐ Others (Specify)

Sample ID	Sampling Depth (m)	Sampling date	Date Arrived Lab	Container No.	Container Type	Container Sample Size	Sample Type Soil/Sediment	Sample Type Water/Crude	Sample Type Sludge	Preserv. (ice, HCl, HNO_3, H_2SO_4, others)	Field Analysis ~~Temp~~ REDOX	pH	EC (mS)	Turb	DO	TDS	Analysis Required
(SED 45) SW45	33	9/9/19		1		SED	SEDIMENT			ICE	-236	7.42					
(SED 33) SW33	33	✓		1			✓			✓	-30.4	7.63					
(SED 17) SW17	33	✓		1			✓			✓	-31.6	7.68					
ASW17	33	✓		1			✓			✓	-33.8	7.74					
ASW18	32	✓		1			✓			✓	-33.8	7.69					
S9	32	✓		1			✓			✓	-22.9	7.37					
SW18	32	✓		1			✓			✓	-33.9	7.71					
S21	32	✓		1			✓			✓	-31.6	7.58					
SW44	29	✓		1			✓			✓	-31.9	7.60					
SW32	29	✓		1			✓			✓	-23.9	7.36					
SW16	29	10/9/19		1			✓			✓	-24.3	7.27					
SW47	36	✓		1			✓			✓	-48.9	7.76					
SW35	36	✓		1			✓			✓	-52.4	7.84					
SW22	36			1			✓			✓	-46.1	7.72					
ASW21	36			1			✓			✓	-45.6	7.70					

Chain of Custody Record

ADESOLA OYESIMI SPDC 10/9/19

OYEBODE TAOFEEK FMENV 10/9/19

OZOEMU, FRED T 10/9/19 BYMENV.

Udeokoro, U. 10/9/19 DPR

ENVIRONMENTAL AND LABORATORY SERVICES	Document Number ELS-FRM-350024
INTERNATIONAL ENERGY SERVICES LIMITED	Revision: 02 / Status: IFA
	Rev. Date: 16/DEC/2011
	Page:1 of 3

CHAIN OF CUSTODY RECORD

Project Title/No: JK EXPLORATION & APPRAISAL WELLS PROJECT.
Client Name: SPDC
Client Project No: IES-ELS-SPDC JK EXPLORATION-18092019-020078
Collection Site: JK DRILLING
No. of Samples: 99 SEDIMENT SAMPLES

Comments:

Turn Around Time: ☐ Standard ☐ Day(s) ☐ Week ☐ Month(s)

Container Type: M=Metal; G=Glass; P=Plastic

Delivered by (Name/Sign.): KOROATT ERIC Date: 18/9/2019 Time____
Received by (Name/Sign.) Kama Ufuoma Date 18/9/2019 Time____

Delivery Method: ☐ In Person ☐ Laboratory. ☐ Courier Service ☐ Others (Specify)

	Sample ID	Sampling Depth (m)	Sampling date	Date Arrived Lab	Container No.	Container Type	Container Sample Size	Sample Type Soil-Sediment	Sample Type Water/Crude	Sample Type Sludge	Preserv. (ice, HCl, HNO$_3$, H$_2$SO$_4$, others)	Field Analysis ~~Temp~~ REDOX	pH	EC (mS)	Turb	DO	TDS	Analysis Required
(SED 45)	SW45	33	9/9/19		1		SED	SEDIMENT			ICE	-236	7.42					
(SED 33)	SW33	33	✓		1			✓			✓	-30.4	7.63					
(SED 17)	SW17	33	✓		1			✓			✓	-31.6	7.68					
	ASW17	33	✓		1			✓			✓	-33.8	7.74					
	ASW18	32	✓		1			✓			✓	-33.8	7.69					
	S9	32	✓		1			✓			✓	-22.9	7.37					
	SW18	32	✓		1			✓			✓	-33.9	7.71					
	S21	32	✓		1			✓			✓	-31.6	7.58					
	SW44	29	✓		1			✓			✓	-31.9	7.60					
	SW32	29	✓		1			✓			✓	-23.9	7.36					
	SW16	29	10/9/19		1			✓			✓	-24.3	7.27					
	SW47	36	✓		1			✓			✓	-48.9	7.76					
	SW35	36	✓		1			✓			✓	-52.4	7.84					
	SW22	36			1			✓			✓	-46.1	7.72					
	ASW21	36			1			✓			✓	-45.6	7.70					

Chain of Custody Record

ADESOLA OJESANMI SPDC 18/9/19

OYEBODE TAOFEEK 10 FMENV 10/9/19

OZOEMU, FRED T 10/9/19 BYMENV.

Udeozor, U. 10/9/19 DPR

Appendix 7
Attendance sheet – Field work

12/09/2019

FIELD DATA GATHERING EXERCISE FOR JK EXPLORATORY AND APPRAISAL WELLS PROJECT

Date:

ATTENDANCE LIST

S/No	NAMES	ORGANISATION	PHONE NUMBER	SIGNATURE
1	OLADUN BODE	IESL	08166470280	
2	Agbakwuru C. Paul	IESL	08068613046	
3	KORSAH ERIC	IESL	08037481143	
4	ADESOLA J. ADESANMI	SPDC	08035705047	
5.	Ani Uchenna. C	IESL	08083745199	
6	YACHAM AUDU	EPANOE	07039756377	
7	Oyebade Tawofeek.	FMENV.	07038202207	
8	EBOH CLEMENT	BL206	BL206	
9	MAKO ONOS VINCENT	BL 206	07052776998	
10	Eke John	BL 206	08057289479	
11	Maduabuchi Henry	SPBC	07056332533	
12	ABRAHAM ELLIOT	BL 206	BL 206	
13	CAPT. PURNAWAN	BL 206		
14	CE FAHED	BL 206		
15	OZOGU, FRED T.	BYMBNV	07037551080	

11/09/2019

FIELD DATA GATHERING EXERCISE FOR JK EXPLORATORY AND APPRAISAL WELLS PROJECT

Date:

ATTENDANCE LIST

S/No	NAMES	ORGANISATION	PHONE NUMBER	SIGNATURE
1.	KURDAH ERIC	IESL	08037481142	
2.	Ani Uchenna. C	IESL	08063745199	
3	YACHAM AMY	EPANDE	07039756377	
4	Madueanusi Henry	SPDC	07056332533	
5.	Oladun Bode	IESL	08166470281	
6.	OMEBODE TAOFEEK	FMENV	07038207207	
7	Agbatewun C. Plus	IESL	08068613046	
8	ADESOLA OLASIMM	SPDC	08035574909	
9	EBOH CLEMENT	BL206	BL206	
10	EKE [illegible]	BL 206	BL206	
11	ABRAHAM ELLIOT	BL 206	BL 206	
12	CAPT. PURNAWAN	BL 206		
13	CE FAHED	BL 206		
14	OKOZU, FRED T.	BYMENV.	07037551080	

Appendix 8
Analytical data

Detailed Results of Air Quality and Meteorology Measurements in the JK Field

Detailed results for Air quality and Meteorology in the JK Field during the Dry season

Parameters	Block D		BLOCK E		BLOCK H		BLOCK C (mini cluster)		BLOCK F		BLOCK G	
	ASW6	ASW 5	ASW8	ASW 7	ASW16	ASW1 5	ASW4	ASW3	ASW10	ASW 9	ASW12	ASW1 1
SO_X	<19.9	<19.9	<19.9	<19.9	<19.9	<19.9	<19.9	<19.9	<19.9	<19.9	<19.9	<19.9
NO_X	9.9	<1.42	<1.42	2.8	2.8	2.8	5.7	5.7	2.8	2.8	4.3	8.52
COx	<8.7	<8.7	<8.7	<8.7	<8.7	<8.7	<8.7	<8.7	<8.7	<8.7	<8.7	<8.7
H_2S	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
C_XH_Y	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Smoke Density	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Wind Direction	N	NE	N	NE	NE	N	NE	NE	N	N	NE	NE
Wind Speed	0.9	0.3	1.7	1.2	3.7	2.4	1.2	1.4	1.6	1.8	3.3	1.4
Amb. Temperature	30.7	33.8	35.7	35.1	33.6	32.6	27.2	29.7	32.6	31.9	31.3	30.1
Relative Humidity	70.1	64.3	59.2	60.8	60.7	69.2	84.4	78.9	70.2	71.1	73.8	80.9
Atm. Pressure	1008	1007	1004	1005	1003	1003	1006	1006	1003	1003	1007	1007
Noise Level	74.3	75.1	75.5	74.9	77.9	76.1	74.9	76.7	76.6	76.4	75.2	75.9
SPM_{10}	19	21	26	24	48	50	46	50	36	40	24	29

Detailed results for Air quality and Meteorology in the JK Field during the Dry season Contd.

Parameters	BLOCK I		BLOCK A		BLOCK J		BLOCK GS		BLOCK K		BLOCK HE	
	ASW20	ASW19	ASW2	ASW1	ASW22	ASW21	ASW14	ASW13	ASW24	ASW23	ASW18	ASW17
SO_X	<19.9	<19.9	<19.9	<19.9	<19.9	<19.9	<19.9	<19.9	<19.9	<19.9	<19.9	<19.9
NO_X	2.8	1.42	4.3	2.8	1.42	2.8	2.8	2.8	7.1	4.3	2.8	5.7
COx	<8.7	<8.7	<8.7	<8.7	<8.7	<8.7	<8.7	<8.7	<8.7	<8.7	<8.7	<8.7
H_2S	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
C_XH_Y	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Smoke Density	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Wind Direction	NW	NW	N	N	NE	NE	SW	SW	NW	NW	NE	NE
Wind Speed	1.7	3.1	0.7	0.8	3.1	2.8	0.9	1.4	2.3	1.7	1	0.6
Amb. Temperature	33.9	31.8	35	35.3	34.1	34.8	34	34.7	29.1	31.1	33.9	31.3
Relative Humidity	68.5	70.3	58.7	58.5	66.9	60.9	62.3	60.4	82.7	80.5	72.4	76.5
Atm. Pressure	1003	1003	1006	1006	1007	1006	1004	1004	1008	1008	1006	1006
Noise Level	76.4	76.2	75.9	77.5	74.9	74.8	75.1	76.3	75.3	75.9	78.4	77.5
SPM_{10}	22	39	23	24	27	30	22	22	28	28	38	23

Appendix 2.1.1: Detailed results for Air quality and Meteorology in the JK Field during the Dry season Contd.

Parameters	Control		
	CNTR1	CNTR 2	CNTR 3
SO_X	<19.9	<19.9	<19.9
NO_X	<1.42	<1.42	<1.42
COx	<8.7	<8.7	<8.7
H_2S	<1.1	<1.1	<1.1
C_XH_Y	<1.0	<1.0	<1.0
Smoke Density	N/A	N/A	N/A
Wind Direction	SW	SW	SW
Wind Speed	3	0.8	2.5
Amb. Temperature	30.5	32.6	32
Relative Humidity	75.3	68.3	69.5
Atm. Pressure	1005	1007	1008
Noise Level	77.9	73.4	75.3
SPM_{10}	32	32	30

Detailed results for Air quality and Meteorology in the JK Field during the Wet season

			Block D		Block E		Block H		Block C		Block F	
Parameter	**UNIT**	**DPR Limit**	**AWS 5**	**ASW 6**	**ASW 7**	**ASW 8**	**ASW 15**	**ASW 16**	**ASW 3**	**ASW 4**	**ASW 9**	**ASW 10**
			14/9/2019	**14/9/2019**	**14/9/2019**	**14/9/2019**	**13/9/2019**	**13/9/2019**	**15/9/2019**	**15/9/2019**	**12/9/2019**	**13/9/2019**
SO_X,	(µg/m^3)	350	<19.9	<19.9	<19.9	<19.9	<19.9	<19.9	<19.9	<19.9	<19.9	<19.9
NO_X	(µg/m^3)	400	<1.42	<1.42	<1.42	<1.42	<1.42	<1.42	<1.42	<1.42	<1.42	<1.42
CO_2	(µg/m^3)	30	<8.7	<8.7	<8.7	<8.7	<8.7	<8.7	<8.7	<8.7	<8.7	<8.7
H_2S	(µg/m^3)	-	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
C_XH_Y	ppm		<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Ozone			0	0	0	0	0	0	0	0	0	0
Wind Direction		N/A	SW	SW	SW	SW	SW	SW	SW	SW	SW	SW
Wind Speed	m/s	N/A	3.9	3.5	2.2	3	2.2	2.9	4.8	5.1	2.5	1.9
Ambient Temperature	(°C)	N/A	30.1	32.3	27.9	29.2	31.2	32.4	29.7	29.9	26.2	32.4
Relative Humidity	%	N/A	78.3	71.2	84	78.8	70.9	68.7	76.6	77.8	90.1	69.3
Atm.Pressure	pa	N/A	1009	1009	1011	1011	1009	1015	1007	1008	1009	1012
Noise Level	(dBA)	80 - 100	73.9	72.8	72.4	73	74.2	75.3	73.8	75.9	75.9	75.6
SPM	(µg/m^3)		31	14	24	29	24	21	19	14	10	31
NH_3	(µg/m^3)		0	0	0	0	0	0	0	0	0	0

Detailed results for Air quality and Meteorology in the JK Field during the Wet season Contd.

			Block G		Block I		Block A		Block J		Block GS	
Parameter	**UNIT**	**DPR Limit**	**ASW 11**	**ASW 12**	**ASW 19**	**AWS 20**	**ASW 1**	**ASW 2**	**ASW 21**	**ASW22**	**ASW 13**	**ASW 14**
			12/9/2019	**12/9/2019**	**12/9/2019**	**13/9/2019**	**15/9/2019**	**15/9/2019**	**10/9/2019**	**10/9/2019**	**11/9/2019**	**11/9/2019**
SO_X,	(µg/m^3)	350	<19.9	<19.9	<19.9	<19.9	<19.9	<19.9	<19.9	<19.9	<19.9	<19.9
NO_X	(µg/m^3)	400	<1.42	<1.42	<1.42	<1.42	<1.42	<1.42	<1.42	<1.42	<1.42	<1.42
CO_2	(µg/m^3)	30	<8.7	<8.7	<8.7	<8.7	<8.7	<8.7	<8.7	<8.7	<8.7	<8.7
H_2S	(µg/m^3)	-	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
C_XH_Y	ppm		<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Ozone			0	0	0	0	0	0	0	0	0	0
Wind Direction		N/A	SW	SW	SW	SW	SW	SW	SW	SW	SW	SW

			Block G		Block I		Block A		Block J		Block GS	
Parameter	**UNIT**	**DPR Limit**	**ASW 11**	**ASW 12**	**ASW 19**	**AWS 20**	**ASW 1**	**ASW 2**	**ASW 21**	**ASW22**	**ASW 13**	**ASW 14**
			12/9/2019	**12/9/2019**	**12/9/2019**	**13/9/2019**	**15/9/2019**	**15/9/2019**	**10/9/2019**	**10/9/2019**	**11/9/2019**	**11/9/2019**
Wind Speed	m/s	N/A	2.9	1.5	2	1.8	3.4	3	5.2	6.2	4.1	3.9
Ambient Temperature	(°C)	N/A	26.2	26.5	28.7	31	29.4	29.7	27.3	27	27.1	27.4
Relative Humidity	%	N/A	91	92	81.5	72.1	76.9	76.8	89.1	91.2	86.3	9.1
Atm.Pressure	pa	N/A	1010	1010	1012	1012	1012	1014	1008	1008	1011	1011
Noise Level	(dBA)	80 - 100	76.3	76.9	73.5	74.9	74.5	74.8	78.6	75.4	76.3	77.4
SPM	(μg/m^3)		24	17	25	29	18	14	15	17	15	11
NH_3	(μg/m^3)		0	0	0	0	0	0	0	0	0	0

Detailed results for Air quality and Meteorology in the JK Field during the Wet season Contd.

			Block K		Block HE		Control		
Parameter	**UNIT**	**DPR Limit**	**AWS 23**	**ASW 24**	**AWS 17**	**ASW 18**	**CTRL 1**	**CTRL 3**	**CTRL 2**
			12/9/2019	**12/9/2019**	**9/9/2019**	**9/9/2019**	**16/9/2019**	**16/9/2019**	**16/9/2019**
SO_X,	(μg/m^3)	350	<19.9	<19.9	<19.9	<19.9	<19.9	<19.9	<19.9
NO_X	(μg/m^3)	400	<1.42	<1.42	<1.42	<1.42	<1.42	<1.42	<1.42
CO_2	(μg/m^3)	30	<8.7	<8.7	<8.7	<8.7	<8.7	<8.7	<8.7
H_2S	(μg/m^3)	-	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
C_XH_Y	ppm		<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Ozone			0	0	0	0	0	0	0
Wind Direction		N/A	SW	SW	SW	SW	SW	SW	SW
Wind Speed	m/s	N/A	4.3	3.5	0.9	0.7	1.3	2.7	1.6
Ambient Temperature	(°C)	N/A	26.2	26.1	35.7	32.4	27	29.8	30.8
Relative Humidity	%	N/A	90.6	90.5	65.1	72.1	87.5	76.2	74
Atm.Pressure	pa	N/A	1012	1012	1011	1011	1013	1010	1010
Noise Level	(dBA)	80 - 100	74.4	75.9	77.4	79.8	73.5	73.7	76.8
SPM	(μg/m^3)		19	22	25	17	18	23	26
NH_3	(μg/m^3)		0	0	0	0	0	0	0

Appendix 2.2: Detailed results for Surface water physicochemical and microbiological measurements in the JK Field

Appendix 2.2.1: Detailed results for Surface water physicochemical and microbiological measurements in the JK Field during dry season

		BLOCK D								BLOCK E						
	200m		500m		800m		1200m		200m		500m		800m		1200m	
Parameters	ASW5	ASW6	SW5	SW6	S3	SW27	S15T	SW39	ASW7	ASW8	SW7	SW8	S4	SW28	S16T	SW40T
Temp. (^oC)	26.3	27.9	29.4	28.2	28.2	28.8	28.3	28.5	28.1	27.3	27.5	28.3	27.2	28.6	27.2	28.3
PH	8.51	8.46	8.53	8.53	8.57	8.48	8.58	8.51	8.53	8.52	8.52	8.5	8.52	8.51	8.53	8.53
EC (µS/cm)	39700	39600	39800	41700	37900	40500	38000	41200	40000	39800	40400	39200	40000	38800	38400	38600
Turb. (NTU)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DO (mg/l)	5.8	5.8	6	5.8	5.7	5.7	5.9	5.7	5.9	5.8	5.8	5.8	5.9	5.9	5.9	5.9
TDS (mg/l)	27792	27741	27862	29190	26530	28352	26612	28841	28000	27860	28280	27441	28000	27160	26880	27022
Cl^- (mg/l)	14336	14300	13867	15058	14192	14625	13722	14878	14444	14372	14589	14156	14372	14011	13393	13939
Alkalinity (mg/l)	16	12	12	12	12	12	16	16	12	16	12	16	12	16	16	16
Colour (mg/l)	0.02	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0	0.01	0	0.01	0.01	0.01	0.01
TSS (mg/l)	24	20	22	20	22	22	20	24	22	20	26	24	18	18	24	18
COD (mg/l)	182	168	149	172	173	183	166	176	160	172	153	169	179	149	180	170
BOD (mg/l)	0.7	1.1	0.8	1.3	0.5	0.5	0.8	0.5	0.5	1	1	0.8	0.3	1.3	0.4	0.8
NO_3^- (mg/l)	1	0.3	1.2	1.8	0.5	1.5	1.2	0.9	0.9	0.3	1.6	0.8	0.9	1.7	0.9	0.9
$N0_2^-$ (mg/l)	3.28	0.98	3.94	5.91	1.64	4.93	3.94	2.96	2.95	0.99	5.28	2.63	2.95	5.58	2.96	2.96
SO_4^{2-} (mg/l)	803	580	680	762	821	876	784	640	790	810	781	762	728	764	640	638
PO_4^{3-} (mg/l)	0.64	0.67	0.42	0.48	0.16	0.34	0.48	0.41	0.23	0.21	0.51	0.52	0.21	0.41	0.38	0.38
NH_4^+ (mg/l)	0.47	0.14	0.57	0.85	0.23	0.7	0.56	0.94	0.41	0.23	0.75	0.38	0.41	0.8	0.44	0.43
O/G (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	<0.001	<0.001	<0.001
THC (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	<0.001	<0.001	<0.001
TPH (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	<0.001	<0.001	<0.001

		BLOCK D								BLOCK E						
	200m		500m		800m		1200m		200m		500m		800m		1200m	
PAH (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	<0.001	<0.001	<0.001
BTEX (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	<0.001	<0.001	<0.001
Ni (mg/l)	0.123	0.351	0.31	0.402	0.124	0.19	0.234	0.23	0.231	0.142	0.124	0.015	0.324	0.234	0.124	0.152
Fe (mg/l)	0.034	0.039	0.131	0.061	0.134	0.083	0.094	0.084	0.115	0.064	0.078	0.064	0.067	0.055	0.051	0.068
Pb (mg/l)	0.326	0.471	0.381	0.426	0.405	0.372	0.382	0.364	0.357	0.266	0.338	0.429	0.365	0.349	0.296	0.391
Cu (mg/l)	0.024	0.014	0.084	0.075	0.029	0.039	0.023	0.045	0.034	0.011	0.062	0.086	0.058	0.031	0.014	0.063
Cr (mg/l)	0.014	0.025	0.047	0.068	0.124	0.223	0.092	0.247	0.24	0.214	0.048	0.072	0.134	0.209	0.124	0.231
Zn (mg/l)	0.017	0.234	0.035	0.041	0.045	0.024	0.027	0.046	0.128	0.034	0.067	0.069	0.022	0.029	0.021	0.003
Cd (mg/l)	0.054	0.035	0.019	0.017	0.063	0.035	0.031	0.052	0.068	0.049	0.039	0.047	0.029	0.061	0.033	0.046
Mn (mg/l)	0.011	0.035	0.073	0.028	0.078	0.027	0.027	0.052	0.045	0.028	0.059	0.05	0.055	0.015	0.027	0.054
Ba (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	<0.01
Co (mg/l)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Hg (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	<0.001	<0.001	<0.001
V (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	<0.001	<0.001	<0.001
K (mg/l)	372	382	345	384	383	376	375	356	372	382	381	376	384	386	386	368
Na (mg/l)	10021	10001	10032	10024	10230	10013	9864	10012	10025	10256	10027	10039	10111	10021	10235	10023
Mg (mg/l)	1218	1215	1325	1230	1240	1375	1101	1235	1225	1258	1142	1132	1422	1285	1240	1123
Ca (mg/l)	403	416	413	418	418	420	421	409	413	409	419	420	413	428	425	406
HUF (cfu/ml)	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL
HUB (cfu/ml) x 10^2	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL
THB (cfu/ml) x 10^2	1.89	1.77	2.32	1.95	1.92	1.92	2.13	1.87	2.11	2.21	1.82	2.12	2.01	2.22	2.12	2.28
THF (cfu/ml) x 10^2	1.67	1.12	1.13	1.22	1.01	1.18	1.21	9.8	1.19	1.07	1.18	1.02	1.31	1.11	1.19	1.32

		BLOCK D								BLOCK E						
	200m		500m		800m		1200 m		200m		500m		800m		1200 m	
SRB (cfu/ml) x 10^3	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Coliforms	0	1	0	0	0	0	0	0	0	0	2	1	2	1	0	0

Appendix 2.2.1: Detailed results for Surface water physicochemical and microbiological measurements in the JK Field during dry season Contd.

	BLOCK H								BLOCK C (mini cluster)							
	200m		500m		800m		1200m		200m		500m		800m		1200m	
Parameters	ASW15	ASW16	SW15	SW16	S8	SW32	S20T	SW44T	ASW3	ASW4	SW3	SW4	S2	SW26	S14T	SW38T
Temp. (°C)	29	28.1	27.3	28.2	29.2	28.5	28.3	28.2	29.3	29.9	28.9	28.2	26.3	28.3	27.3	28.5
PH	8.54	8.54	8.54	8.59	8.54	8.57	8.54	8.52	8.54	8.57	8.56	8.56	8.55	8.56	8.56	8.56
EC (µS/cm)	40700	41100	39900	38000	39400	40800	38900	40500	39300	39000	39900	40500	39700	41100	39500	39700
Turb. (NTU)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DO (mg/l)	5.9	5.9	5.9	5.8	5.9	5.8	5.9	5.8	5.9	5.9	6.1	5.8	6	5.8	6	6
TDS (mg/l)	28490	28773	27930	26600	27583	28560	27230	28350	27510	27300	29981	28353	27971	28778	27650	27790
Cl^- (mg/l)	14697	14842	14408	13722	14228	14733	14032	14625	14192	14625	14083	14625	14336	14842	13291	14336
Alkalinity (mg/l)	12	16	12	12	8	16	16	16	10	12	16	16	12	14	16	12
Colour (mg/l)	0.02	0.01	0	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.01
TSS (mg/l)	20	20	20	22	16	24	20	26	18	20	26	24	20	18	22	20
COD (mg/l)	165	171	182	167	173	184	192	181	178	169	163	172	169	170	175	184
BOD (mg/l)	0.5	0.7	0.6	0.5	0.3	0.2	1.3	0.7	0.7	0.6	1	0.6	0.7	0.7	0.6	0.6

	BLOCK H								BLOCK C (mini cluster)							
	200m		500m		800m		1200m		200m		500m		800m		1200m	
NO_3^- (mg/l)	0.9	0.3	1.6	0.8	0.5	0.8	1.4	1.2	0.5	0.8	1.8	1.8	1	1.4	0.7	1.4
$N0_2^-$ (mg/l)	2.95	0.98	5.28	2.63	1.64	2.63	4.59	3.94	1.62	2.63	5.91	5.93	3.28	4.59	2.29	4.597
SO_4^{2-} (mg/l)	803	920	790	681	734	685	862	681	730	810	698	695	750	869	768	848
PO_4^{3-} (mg/l)	0.23	0.51	0.5	0.41	0.31	0.32	0.42	0.38	0.39	0.28	0.41	0.38	0.88	0.32	0.48	0.46
NH_4^+ (mg/l)	0.41	0.14	0.76	0.36	0.23	0.36	0.66	0.56	0.25	0.37	0.85	0.84	0.47	0.66	0.32	0.42
O/G (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	<0.001	<0.001	<0.001
THC (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	<0.001	<0.001	<0.001
TPH (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	<0.001	<0.001	<0.001
PAH (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	<0.001	<0.001	<0.001
BTEX (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	<0.001	<0.001	<0.001
Ni (mg/l)	0.767	0.342	0.122	0.089	0.312	0.143	0.211	0.112	0.325	0.03	0.135	0.028	0.236	0.124	0.418	0.412
Fe (mg/l)	0.068	0.053	0.081	0.069	0.125	0.109	0.124	0.063	0.036	0.025	0.039	0.052	0.121	0.036	0.117	0.053
Pb (mg/l)	0.491	0.269	0.298	0.412	0.392	0.336	0.342	0.321	0.422	0.294	0.295	0.324	0.339	0.283	<0.001	0.294
Cu (mg/l)	0.038	0.017	0.023	0.028	0.071	0.061	0.073	0.022	0.045	0.075	0.024	0.034	0.078	0.021	0.021	0.063
Cr (mg/l)	<0.001	0.023	0.253	0.086	0.012	0.195	0.243	0.028	0.045	<0.001	0.026	0.034	0.026	0.267	0.249	0.218
Zn (mg/l)	0.086	0.018	0.091	0.056	0.033	0.067	<0.001	0.034	0.032	<0.001	0.047	0.051	0.026	0.026	<0.001	0.013
Cd (mg/l)	0.065	0.072	0.022	0.037	0.056	0.072	0.028	0.061	0.075	0.081	0.075	0.068	0.021	0.022	0.065	0.057
Mn (mg/l)	<0.001	0.018	0.049	0.073	0.048	0.052	<0.001	0.074	0.024	0.111	0.011	0.089	0.037	0.026	0.018	0.071
Ba (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	<0.01

	BLOCK H								BLOCK C (mini cluster)							
	200m		500m		800m		1200m		200m		500m		800m		1200m	
Co (mg/l)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Hg (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	<0.001	<0.001	<0.001
V (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	<0.001	<0.001	<0.001
K (mg/l)	369	356	362	372	362	372	370	372	350	369	382	375	377	370	392	345
Na (mg/l)	10448	10231	10125	10256	9856	10026	9354	10231	10014	9816	10024	10028	10045	10018	9619	10056
Mg (mg/l)	1207	1215	1234	1244	1224	1248	1198	1236	1226	1235	1248	1124	1235	1238	1250	1238
Ca (mg/l)	402	412	410	421	400	428	405	403	418	412	410	412	414	418	406	410
HUF (cfu/ml)	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL
HUB (cfu/ml) x 10^2	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL
THB (cfu/ml) x 10^2	2.01	2.11	2.12	2.25	1.83	1.84	2.28	2.28	2.41	2.09	2.21	2.19	2.24	2.01	2.02	2.01
THF (cfu/ml) x 10^2	1.18	1.32	1.28	1.31	1.02	1.21	1.28	1.32	1.02	1.53	1.21	1.02	1.07	1.25	1.22	1.28
SRB (cfu/ml) x 10^3	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Coliforms	1	0	0	0	0	4	0	0	0	0	1	0	1	0	0	0

Appendix 2.2.1: Detailed results for Surface water physicochemical and microbiological measurements in the JK Field during dry season Contd.

	BLOCK F								BLOCK G									
	200m		500m		800m		1200m		200m				500m		800m		1200m	
Parameters	ASW9	ASW10	SW9	SW10T	S5	SW29	S17T	SW41T	ASW11	ASW12T	ASW12M	ASW12B	SW11T	SW12	S6T	SW30	S18	SW42T
Temp. (°C)	29.2	29.2	29	28.9	28.2	28.4	29.4	28.6	27.8	28.7	28.1	27.4	28.2	28	30.2	28	29.7	28.9
PH	8.55	8.54	8.52	8.53	8.55	8.54	8.53	8.52	8.58	8.58	8.58	8.59	8.55	8.53	8.57	8.53	8.58	8.57
EC (µS/cm)	39600	40100	40200	39800	38400	40100	39800	39500	41100	40400	43000	47000	38400	40400	40500	40300	40600	41100
Turb. (NTU)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DO (mg/l)	5.9	6	5.9	6	5.8	5.9	6	5.9	6	6.1	4.1	3.4	5.8	6	6.1	5.9	6	6
TDS (mg/l)	27720	28074	28140	27860	26880	28071	27862	27650	28770	28281	30100	32920	26880	28290	28350	28212	28421	28770
Cl^- (mg/l)	14300	14480	14519	14697	14372	14480	13163	14264	14842	14589	15528	16972	14878	14589	14336	14553	12882	14842
Alkalinity (mg/l)	12	12	12	16	10	12	16	16	12	12	10	14	14	12	16	12	12	12
Colour (mg/l)	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0	0.01	0.01	0.01	0	0.01	0	0	0.01	0.01	0.01
TSS (mg/l)	18	18	28	22	18	22	22	26	16	22	28	36	20	18	18	22	18	20
COD (mg/l)	167	190	158	172	184	157	175	177	168	172	166	171	165	190	180	163	177	205
BOD (mg/l)	1.3	0.7	0.7	0.6	0.5	0.3	0.7	0.9	0.5	1.2	0.8	0.6	0.6	1.1	0.7	0.7	1.1	0.5
NO_3^- (mg/l)	0.7	0.3	1	1.4	1.3	1.7	1.6	0.8	0.7	0.3	0.5	0.9	1.4	0.9	1.1	1.4	1.2	0.9
$N0_2^-$ (mg/l)	2.29	0.98	3.29	4.51	4.27	5.58	5.25	2.62	2.29	0.98	1.64	2.99	4.51	2.96	3.61	4.59	3.94	2.96
SO_4^{2-} (mg/l)	912	720	781	824	840	690	742	690	903	775	792	784	852	862	810	694	650	881

	BLOCK F								BLOCK G									
	200m		500m		800m		1200m		200m				500m		800m		1200m	
Parameters	ASW9	ASW10	SW9	SW10T	S5	SW29	S17T	SW41T	ASW11	ASW12T	ASW12M	ASW12B	SW11T	SW12	S6T	SW30	S18	SW42T
PO_4^{3-} (mg/l)	0.83	0.49	0.42	0.41	0.18	0.38	0.46	0.24	0.21	0.5	0.29	0.43	0.46	0.38	0.27	0.36	0.34	0.34
NH_4^+ (mg/l)	0.35	0.14	1.46	0.68	0.6	0.79	0.74	0.36	0.32	0.14	0.23	0.41	0.66	0.45	0.51	0.68	0.56	0.44
O/G (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	<0.001	<0.001	<0.001	<0.001	<0.001
THC (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	<0.001	<0.001	<0.001	<0.001	<0.001
TPH (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	<0.001	<0.001	<0.001	<0.001	<0.001
PAH (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	<0.001	<0.001	<0.001	<0.001	<0.001
BTEX (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	<0.001	<0.001	<0.001	<0.001	<0.001
Ni (mg/l)	0.231	0.68	0.082	0.045	0.325	0.308	0.221	0.226	0.321	0.516	0.531	0.808	0.23	0.014	0.312	0.522	0.138	0.012
Fe (mg/l)	0.025	0.122	0.046	0.062	0.114	0.067	0.081	0.049	0.098	0.053	0.172	0.186	0.049	0.125	0.096	0.081	0.064	0.113
Pb (mg/l)	0.258	0.545	0.198	0.055	0.284	0.368	0.327	0.315	0.321	0.308	0.335	0.36	0.343	0.358	0.367	0.299	0.159	0.331
Cu (mg/l)	0.024	0.067	0.031	0.052	0.047	0.065	0.023	0.047	0.018	0.038	0.08	0.052	0.062	0.059	0.018	0.034	0.06	0.034
Cr (mg/l)	0.056	<0.001	0.024	0.399	0.089	0.235	0.136	0.21	0.082	0.122	0.031	0.294	0.252	0.283	0.026	0.258	0.174	0.024
Zn (mg/l)	0.022	0.023	0.045	0.111	0.074	0.037	0.012	<0.001	0.024	0.133	<0.001	<0.001	0.076	0.117	0.066	0.015	0.03	0.021
Cd (mg/l)	0.036	0.007	0.048	0.108	0.035	0.046	0.023	0.033	0.027	0.061	0.063	0.06	0.034	0.096	0.017	0.022	0.153	0.022
Mn (mg/l)	0.098	<0.001	0.06	0.07	0.098	0.039	0.029	0.045	0.075	<0.001	0.097	0.09	0.07	0.084	0.042	0.027	0.012	0.017
Ba (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	<0.01	<0.01	<0.01

	BLOCK F								BLOCK G									
	200m		500m		800m		1200m		200m				500m		800m		1200m	
Parameters	ASW9	ASW10	SW9	SW10T	S5	SW29	S17T	SW41T	ASW11	ASW12T	ASW12M	ASW12B	SW11T	SW12	S6T	SW30	S18	SW42T
Co (mg/l)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Hg (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	<0.001	<0.001	<0.001	<0.001	<0.001
V (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	<0.001	<0.001	<0.001	<0.001	<0.001
K (mg/l)	378	336	370	374	380	387	372	370	329	345	335	332	356	357	359	385	378	368
Na (mg/l)	10245	9532	10040	9987	10234	10024	10026	10016	9989	9391	9714	9829	9998	10121	10124	10031	9619	10024
Mg (mg/l)	1240	1189	1212	1114	1124	1345	1342	1233	1235	1102	1291	1264	1206	1080	1212	1248	1223	1235
Ca (mg/l)	411	394	421	396	417	412	401	408	386	406	401	403	406	409	421	423	405	412
HUF (cfu/ml)	NIL	0.10X101	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL
HUB (cfu/ml) x 10^2	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL
THB (cfu/ml) x 10^2	1.95	2.31	2.33	2.18	1.78	2.09	2.37	2.16	2.02	2.12	1.86	2.17	1.83	1.95	2.35	2.34	2.41	2.31
THF (cfu/ml) x 10^2	1.38	1.56	1.17	1.12	1.21	1.22	1.18	1.24	1.33	1.17	1.12	1.43	1.13	1.25	1.03	1.06	1.11	1.12
SRB (cfu/ml) x 10^3	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Coliforms	2	0	0	0	0	0	0	0	0	2	0	2	0	0	0	1	0	0

Appendix 2.2.1: Detailed results for Surface water physicochemical and microbiological measurements in the JK Field during dry season Contd.

	BLOCK I										BLOCK A							
	200m		500m				800m		1200 m		200m		500 m		800 m		1200 m	
Parameters	ASW19	ASW20	SW19T	SW19M	SW19B	SW20	S10	SW34	S22T	SW46T	ASW1	ASW2	SW1	SW2	S1	SW25	S13T	SW37T
Temp. (°C)	30.7	30.1	32	29.6	29	30.5	29.4	30.8	28.6	28.2	28.5	28.2	28.8	28.4	28.1	30.2	28.3	28.9
PH	8.53	8.53	8.54	8.56	8.56	8.54	8.52	8.52	8.55	8.52	8.53	8.51	8.53	8.51	8.54	8.49	8.53	8.52
EC (µS/cm)	41400	41100	40600	44000	44300	41200	40700	41200	40700	40500	40500	40600	40300	40900	40400	41600	40000	40.3
Turb. (NTU)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DO (mg/l)	6	6	6.1	4	3.4	6.1	6	6	6	5.8	5.9	5.8	5.9	5.8	5.9	6	5.9	5.9
TDS (mg/l)	28982	24660	28422	30800	31012	28842	28500	28840	28491	28350	28354	28427	28210	28631	28281	29127	28000	28210
Cl^- (mg/l)	14950	14842	14697	15853	16322	14878	14480	14878	14697	14625	14625	14620	14553	14552	14589	15022	11553	14522
Alkalinity (mg/l)	12	16	10	16	14	12	14	12	12	16	16	12	16	12	14	12	16	10
Colour (mg/l)	0.01	0	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0	0.01	0.01	0.01	0.01	0	0.01
TSS (mg/l)	20	22	18	28	26	26	24	22	18	26	20	22	22	28	22	20	32	24
COD (mg/l)	180	167	182	174	170	164	171	157	190	181	162	153	169	182	173	168	192	167
BOD (mg/l)	0.5	0.8	0.5	0.3	0.2	0.4	0.8	0.8	0.7	0.7	0.9	0.5	0.9	1.2	0.3	0.2	0.8	0.5
NO_3^- (mg/l)	0.9	0.5	1.3	1.4	1.6	0.8	1.1	0.6	1.4	1.2	0.2	0.5	1.9	0.6	1.2	0.7	0.8	1.2
$N0_2^-$ (mg/l)	2.99	1.64	4.27	4.59	5.25	2.62	3.61	1.97	4.51	3.94	0.68	1.64	4.51	1.97	3.94	2.29	2.63	3.94
SO_4^{2-} (mg/l)	815	802	682	781	784	864	920	676	762	681	640	610	782	780	807	751	670	695

	BLOCK I										BLOCK A							
	200m		500m				800m		1200m		200m		500m		800m		1200m	
PO_4^{3-} (mg/l)	0.43	0.29	0.48	0.32	0.36	0.34	0.47	0.42	0.36	0.38	0.11	0.15	0.32	0.36	0.61	0.48	0.24	0.54
NH_4^+ (mg/l)	0.43	0.23	0.6	0.65	0.75	0.38	0.51	0.28	0.68	0.56	0.09	0.23	0.68	0.28	0.55	0.32	0.37	0.56
O/G (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	<0.001	<0.001	<0.001	<0.001	<0.001
THC (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	<0.001	<0.001	<0.001	<0.001	<0.001
TPH (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	<0.001	<0.001	<0.001	<0.001	<0.001
PAH (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	<0.001	<0.001	<0.001	<0.001	<0.001
BTEX (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	<0.001	<0.001	<0.001	<0.001	<0.001
Ni (mg/l)	0.253	0.234	0.238	0.278	0.293	0.012	0.707	0.068	0.134	0.098	0.243	0.212	0.312	0.421	0.346	0.245	0.232	0.465
Fe (mg/l)	0.064	0.029	0.068	0.084	0.132	0.056	0.074	0.038	0.071	0.057	0.042	0.018	0.068	0.045	0.086	0.114	0.072	0.063
Pb (mg/l)	0.335	0.318	0.371	0.405	0.428	0.204	0.249	0.342	0.223	0.129	0.412	0.385	0.389	0.352	0.205	0.339	0.395	<0.001
Cu (mg/l)	0.024	0.011	0.032	0.049	0.072	0.077	0.036	0.052	0.053	0.051	0.08	0.025	0.023	0.011	0.071	0.033	0.018	0.054
Cr (mg/l)	0.045	0.024	0.005	0.013	0.029	0.243	0.014	0.219	0.226	0.017	0.329	0.12	0.113	0.015	0.151	0.232	0.118	0.314
Zn (mg/l)	0.03	0.071	0.096	0.118	0.132	0.043	0.022	0.009	0.032	0.005	0.007	0.012	0.022	0.032	0.027	0.037	0.064	0.145
Cd (mg/l)	0.068	0.054	0.042	0.065	0.073	0.045	0.052	0.061	0.045	0.041	0.052	0.054	0.041	0.052	0.046	0.028	0.026	0.022
Mn (mg/l)	0.054	0.037	0.033	0.054	0.081	0.04	0.075	0.055	0.023	0.077	0.042	0.014	0.023	0.042	0.023	0.015	0.021	0.049
Ba (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	<0.01	<0.01	<0.01
Co (mg/l)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

	BLOCK I										BLOCK A							
	200m		500m				800m		1200 m		200m		500 m		800 m		1200 m	
Hg (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	<0.001	<0.001	<0.001	<0.001	<0.001
V (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	<0.001	<0.001	<0.001	<0.001	<0.001
K (mg/l)	338	326	384	346	342	355	377	378	377	368	387	386	386	365	371	372	391	376
Na (mg/l)	10212	9865	9989	9945	10235	9884	9586	10065	9976	10350	10079	10010	10021	10010	10074	10014	9499	10036
Mg (mg/l)	1228	1240	1245	1126	1128	1236	1160	1234	1226	1268	1157	1120	1134	1124	1241	1236	1232	1245
Ca (mg/l)	415	418	427	397	385	405	411	412	414	406	409	410	406	409	409	415	404	416
HUF (cfu/ml)	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL						
HUB (cfu/ml) x 10^2	NIL	NIL	NIL	NIL	NIL	NIL	0.10X101	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL
THB (cfu/ml) x 10^2	1.93	2.14	1.77	2.02	2.31	1.81	2.11	2.13	2.1	2.11	2.21	1.93	NIL	NIL	NIL	NIL	NIL	NIL
THF (cfu/ml) x 10^2	1.02	1.16	1.33	1.28	1.09	1.24	1.08	1.21	1.36	1.25	1.61	1.22	2.23	2.09	2.17	2.19	2.07	2.26
SRB (cfu/ml) x 10^3	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.15	1.06	1.12	1.27	1.16	0.9
Coliforms	0	2	0	0	0	0	0	1	0	0	0	0	NA	NA	NA	NA	NA	NA

Appendix 2.2.1: Detailed results for Surface water physicochemical and microbiological measurements in the JK Field during dry season Contd.

	BLOCK J								BLOCK GS							
	200m		500m		800m		1200 m		200m		500m		800m		1200 m	
Parameters	ASW21	ASW22	SW21	SW22	S11	SW35	S23T	SW47T	ASW13	ASW14	SW13	SW14	S7	SW31	S19T	SW43T
Temp. (°C)	28.6	29.1	28.9	28.4	29.9	28.7	28.7	31.5	29	28	27.5	28.2	27.9	28.5	27.9	28.3
PH	8.57	8.51	8.57	8.56	8.54	8.56	8.57	8.52	8.52	8.56	8.53	8.54	8.51	8.56	8.54	8.48
EC (µS/cm)	41100	41100	41700	40700	40600	40500	40800	40700	40900	40900	41400	40900	41200	41000	40700	40900
Turb. (NTU)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DO (mg/l)	6	6.1	6.1	6.1	6	6.1	6.1	6	5.9	5.8	5.9	5.9	5.9	5.8	6	6
TDS (mg/l)	28770	28771	29198	28492	28420	28357	28560	28492	28630	28630	28982	28630	28841	28700	28491	28630
Cl^- (mg/l)	14444	14697	14842	14697	14480	14625	14733	14697	14842	14625	14769	14769	14878	14806	13751	14769
Alkalinity (mg/l)	12	16	12	12	12	12	16	12	12	12	12	16	16	16	16	16
Colour (mg/l)	0	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0	0	0	0.01	0.01	0.01
TSS (mg/l)	20	24	22	18	22	24	20	26	20	24	18	20	16	26	26	18
COD (mg/l)	175	177	172	163	180	201	177	168	175	169	183	175	180	172	173	178
BOD (mg/l)	0.4	0.4	0.7	0.3	0.4	0.7	0.8	0.5	0.5	0.3	1	0.8	0.7	0.5	0.6	0.6
NO_3^- (mg/l)	0.3	0.5	0.9	1	0.8	0.8	0.9	0.9	0.4	0.8	1.6	1.8	0.8	0.9	0.8	1
$N0_2^-$ (mg/l)	0.98	1.64	2.96	3.28	2.63	2.63	2.96	2.96	1.31	2.63	5.28	5.91	2.63	2.96	2.63	3.28
SO_4^{2-} (mg/l)	887	670	682	684	855	781	796	861	925	871	843	840	810	784	682	691
PO_4^{3-} (mg/l)	0.24	0.31	0.41	0.52	0.28	0.95	0.46	0.6	0.25	0.28	0.44	0.46	0.31	0.91	0.3	0.38

	BLOCK J								BLOCK GS							
	200m		500m		800m		1200m		200m		500m		800m		1200m	
Parameters	ASW21	ASW22	SW21	SW22	S11	SW35	S23T	SW47T	ASW13	ASW14	SW13	SW14	S7	SW31	S19T	SW43T
NH_4^+ (mg/l)	0.14	0.23	0.44	0.46	0.37	0.36	0.44	0.45	0.28	0.37	0.75	0.84	0.37	0.42	0.38	0.47
O/G (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	<0.001	<0.001	<0.001
THC (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	<0.001	<0.001	<0.001
TPH (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	<0.001	<0.001	<0.001
PAH (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	<0.001	<0.001	<0.001
BTEX (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	<0.001	<0.001	<0.001
Ni (mg/l)	1.038	0.326	0.405	0.148	0.486	0.123	0.385	0.178	0.375	0.128	0.018	0.098	1.099	0.421	0.124	0.208
Fe (mg/l)	0.124	0.098	0.083	0.051	0.038	0.124	0.062	0.083	0.113	0.107	0.098	0.064	0.068	0.054	0.049	0.083
Pb (mg/l)	0.309	0.422	0.249	0.325	0.204	0.358	<0.001	0.158	0.423	0.335	0.349	0.316	0.42	0.324	0.225	0.325
Cu (mg/l)	0.059	0.012	0.061	0.075	0.053	0.063	0.07	0.014	0.049	0.024	0.034	0.057	0.084	0.028	0.026	0.013
Cr (mg/l)	0.067	0.042	0.211	0.229	<0.001	0.228	0.156	0.028	0.191	0.023	0.257	0.189	0.226	0.23	0.216	0.025
Zn (mg/l)	<0.001	0.028	0.054	0.047	0.062	0.052	<0.001	0.024	0.015	0.022	0.063	0.039	<0.001	0.093	<0.001	0.001
Cd (mg/l)	0.09	0.039	0.039	0.083	0.049	0.044	0.069	0.061	0.005	0.078	0.054	0.081	0.094	0.051	0.017	0.024
Mn (mg/l)	0.05	0.025	0.052	0.062	<0.001	0.063	0.08	0.053	0.038	0.034	0.093	0.026	0.084	0.046	0.021	0.06
Ba (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	<0.01
Co (mg/l)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Hg (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	<0.001	<0.001	<0.001
V (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	<0.001	<0.001	<0.001

	BLOCK J								BLOCK GS							
	200m		500m		800m		1200 m		200m		500m		800m		1200 m	
Parameters	ASW21	ASW22	SW21	SW22	S11	SW35	S23T	SW47T	ASW13	ASW14	SW13	SW14	S7	SW31	S19T	SW43T
K (mg/l)	359	362	365	372	389	356	385	372	331	325	346	355	358	387	377	372
Na (mg/l)	10178	9978	10235	10052	9252	10023	9078	10245	10211	10222	10210	10023	9320	10028	9869	10325
Mg (mg/l)	1258	1111	1200	1213	1290	1023	1241	1243	1214	1232	1258	10051	1253	1345	1235	1250
Ca (mg/l)	407	420	417	426	407	414	402	418	403	408	415	413	407	423	402	403
HUF (cfu/ml)	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL
HUB (cfu/ml) x 10^2	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	2	NIL	NIL	NIL	NIL	NIL	NIL	NIL
THB (cfu/ml) x 10^2	2.13	2.13	2.14	2.32	2.13	1.98	2.23	2.16	1.99	2.13	2.07	2.21	2.41	1.92	2.03	2.35
THF (cfu/ml) x 10^2	1.21	1.11	1.04	1.27	1.21	1.03	1.21	1.03	1.09	1.11	1.01	1.15	1.28	1.34	1.12	1.19
SRB (cfu/ml) x 10^3	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Coliforms	0	1	0	0	0	0	0	0	0	0	2	0	0	0	0	0

Appendix 2.2.1: Detailed results for Surface water physicochemical and microbiological measurements in the JK Field during dry season Contd.

	BLOCK K								BLOCK HE								Control		
	200m		500m		800m		1200m		200m		500m		800m		1200m				
Parameters	ASW23	ASW24	SW23	SW24	S12	SW36	S24T	SW48T	ASW17	ASW18	SW17	SW18T	S9	SW33	S21T	SW45T	CONTL 1 TP	CONTL 2 TP	CONTL 3 TP
Temp. (^oC)	28.5	29.3	28.9	28.9	29.8	28	29	28.1	29	28.7	28.7	27.5	28.3	28.9	28.4	28	28.6	28.3	29.1
PH	8.59	8.58	8.59	8.59	8.59	8.57	8.57	8.59	8.54	8.51	8.53	8.53	8.55	8.57	8.52	8.55	8.51	8.57	8.51
EC (µS/cm)	41500	41400	41500	40900	40400	40900	40900	40800	40100	40000	39800	39900	40000	41700	39700	39500	42100	41900	38300
Turb. (NTU)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DO (mg/l)	6.1	6.1	6.1	6.1	6	6.2	6	6.1	5.8	5.8	5.8	5.8	5.8	6.1	5.9	5.8	6	6	6
TDS (mg/l)	29071	28982	29061	28630	28287	28633	28630	28560	28070	28000	27860	27930	28000	29198	27790	27650	29470	29330	26813
Cl^- (mg/l)	14842	14528	14842	14769	11502	14733	14769	14733	14461	14444	14444	14408	14444	14300	14336	14264	15203	15131	13831
Alkalinity (mg/l)	12	16	14	16	16	12	16	16	12	12	16	12	12	16	16	16	12	16	8
Colour (mg/l)	0.01	0	0	0	0.01	0.01	0.01	0.01	0.01	0	0.01	0.01	0.01	0	0.01	0.01	0.01	0.01	0.01
TSS (mg/l)	24	20	24	20	24	20	16	20	18	18	24	24	26	24	20	20	22	22	20
COD (mg/l)	172	185	178	173	172	168	175	189	179	184	159	163	168	169	175	201	199	179	186
BOD (mg/l)	0.7	0.5	0.7	0.5	0.6	0.1	1.1	0.2	0.5	0.6	0.7	0.9	0.5	0.4	0.9	0.4	0.5	0.9	0.6
NO_3^- (mg/l)	0.7	0.9	1.4	0.8	0.7	0.9	0.9	0.8	0.4	0.7	0.9	1	0.7	0.9	0.8	0.7	1.2	0.9	0.9
$N0_2^-$ (mg/l)	2.29	2.96	4.59	2.63	2.29	2.96	2.96	2.63	1.31	2.29	2.96	3.28	2.99	2.96	2.63	2.29	3.94	2.96	2.96

	BLOCK K								BLOCK HE								Control		
	200m		500m		800m		1200m		200m		500m		800m		1200m				
Parameters	ASW23	ASW24	SW23	SW24	S12	SW36	S24T	SW48T	ASW17	ASW18	SW17	SW18T	S9	SW33	S21T	SW45T	CONTL 1 TP	CONTL 2 TP	CONTL 3 TP
SO_4^{2-} (mg/l)	720	832	723	742	650	791	824	659	811	704	691	652	801	698	651	693	687	789	714
PO_4^{3-} (mg/l)	0.17	0.25	0.5	0.42	0.2	0.51	0.38	0.24	0.29	0.83	0.46	0.54	0.28	0.31	0.24	0.41	0.42	0.42	0.41
NH_4^+ (mg/l)	0.32	0.41	0.68	0.36	0.34	0.43	0.45	0.36	0.28	0.35	0.42	0.47	0.33	0.42	0.36	0.33	0.56	0.43	0.43
O/G (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	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
THC (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	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
TPH (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	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
PAH (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	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
BTEX (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	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Ni (mg/l)	0.235	0.412	0.23	0.325	0.287	0.254	0.123	0.045	0.421	0.449	0.078	0.098	0.277	0.205	0.268	0.245	0.764	0.974	0.133
Fe (mg/l)	0.113	0.109	0.063	0.049	0.069	0.084	0.029	0.063	0.075	0.119	0.125	0.103	0.082	0.067	0.047	0.068	0.024	0.014	0.437
Pb (mg/l)	0.298	0.327	0.414	0.327	0.354	0.327	0.352	0.116	0.411	0.38	0.328	<0.001	<0.001	0.349	0.03	0.356	0.094	0.289	<0.001
Cu (mg/l)	0.026	0.024	0.053	0.029	0.118	0.049	0.136	0.018	0.027	0.015	0.062	0.025	0.039	0.038	0.068	0.032	0.025	0.022	0.029
Cr (mg/l)	0.024	0.018	0.012	0.186	0.145	0.261	0.268	0.038	0.031	0.162	0.194	0.182	<0.001	0.211	0.194	0.041	0.166	0.172	<0.001
Zn (mg/l)	0.068	0.035	0.005	0.019	0.015	0.006	0.011	0.03	0.057	0.044	0.061	0.036	0.06	0.038	0.043	0.027	0.01	0.038	0.008
Cd (mg/l)	0.037	0.039	0.012	0.036	0.038	0.068	0.024	0.048	0.052	0.095	0.041	0.011	0.041	0.044	0.071	0.026	0.018	0.009	<0.001
Mn (mg/l)	0.085	0.082	0.053	0.021	0.019	0.061	0.034	0.046	0.029	0.057	0.049	0.023	<0.001	0.039	<0.001	0.062	0.122	0.051	0.075

	BLOCK K								BLOCK HE								Control		
	200m		500m		800m		1200m		200m		500m		800m		1200m				
Parameters	ASW23	ASW24	SW23	SW24	S12	SW36	S24T	SW48T	ASW17	ASW18	SW17	SW18T	S9	SW33	S21T	SW45T	CONTL1 TP	CONTL2 TP	CONTL3 TP
Ba (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	<0.01	<0.01	<0.01	<0.01
Co (mg/l)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Hg (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	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
V (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	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
K (mg/l)	375	378	354	371	385	389	375	327	372	342	380	371	386	356	369	365	376.6	379.9	390.4
Na (mg/l)	9897	10124	10090	10012	9568	10045	10123	10142	9865	10115	10241	9989	9134	10075	9423	10124	9948	9863	9563
Mg (mg/l)	1242	1124	1224	1245	1288	1234	1212	1231	1113	1213	1228	1255	1159	1213	1211	1242	1124	1243	1145
Ca (mg/l)	421	419	406	412	408	413	403	420	421	407	428	401	410	410	408	412	400	406	408
HUF (cfu/ml)	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL
HUB (cfu/ml) x 10^2	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL
THB (cfu/ml) x 10^2	2.28	1.86	1.94	1.82	2.32	2.11	2.23	1.83	2.31	2.18	2.19	1.98	1.68	1.81	2.03	2.32	2.13	2.37	2.19
THF (cfu/ml) x 10^2	1.03	1.18	1.16	1.32	1.09	1.23	1.19	1.01	1.09	1.14	1.23	1.14	1.12	1.07	1.31	1.17	1.11	1.02	1.03
SRB (cfu/ml) x 10^3	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

	BLOCK K								BLOCK HE								Control		
	200m		500m		800m		1200m		200m		500m		800m		1200m				
Parameters	ASW23	ASW24	SW23	SW24	S12	SW36	S24T	SW48T	ASW17	ASW18	SW17	SW18T	S9	SW33	S21T	SW45T	CONTL 1 TP	CONTL 2 TP	CONTL 3 TP
Coliforms	0	0	2	0	0	3	0	0	0	0	0	1	2	3	0	0	0	0	0

Appendix 2.2.2: Detailed results for Surface water physicochemical and microbiological measurements in the JK Field during wet season

		BLOCK D								BLOCK E						
	200m		500m		800m		1200m		200m		500m		800m		1200m	
Parameters	ASW5	ASW6	SW5	SW6	S3	SW27	S15T	SW39	ASW7	ASW8	SW7	SW8	S4	SW28	S16T	SW40T
Temp. (°C)	28.3	28.4	28.4	27.9	27.2	27.6	27.7	27.4	27.6	28.1	28.1	28.3	28	27.7	28.1	27.7
PH	8.49	8.32	8.39	8.37	8.4	8.34	8.41	8.26	8.29	8.44	8.36	8.41	8.25	8.29	8.3	8.39
EC (µS/cm)	37600	37300	37800	38900	35700	43500	37600	36800	40400	38500	40500	42500	37300	40400	34100	41700
Turb. (NTU)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DO (mg/l)	5.9	6	5.9	5.9	5.9	5.9	5.9	6.1	5.8	6	5.8	5.9	5.9	5.8	6	5.9
TDS (mg/l)	26320	26110	26460	27230	24990	30450	26320	25860	28280	26950	28350	29750	26010	28280	23870	29190
Cl^- (mg/l)	15052	14910	15137	15563	14285	17409	15052	14711	15392	16159	16216	17011	16926	16159	13460	16670
Alkalinity (mg/l)	16	12	12	12	8	8	16	12	12	16	8	16	12	12	16	12
Colour (mg/l)	0	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0	0.01	0	0.01	0.01	0.01	0.01
TSS (mg/l)	20	22	20	20	22	22	20	20	20	18	22	24	16	18	24	22
COD (mg/l)	180	164	160	166	172	186	164	174	160	174	158	164	178	154	182	172
BOD (mg/l)	1.6	1.2	0.5	0.8	0.6	1.5	0.6	2.3	0.8	1	0.8	1	1	1	0.6	0.6
NO_3^- (mg/l)	2	3.4	1.6	1.7	0.8	1.4	0.8	1.9	2.4	1.9	1.8	1.5	0.9	1.7	0.9	0.7
$N0_2^-$ (mg/l)	1.48	2.51	1.18	1.25	0.59	1.03	0.59	1.4	1.77	1.4	1.33	1.11	0.66	1.25	0.66	1.25

		BLOCK D								BLOCK E						
	200m		500m		800m		1200 m		200m		500m		800m		1200 m	
Parameters	ASW5	ASW6	SW5	SW6	S3	SW27	S15T	SW39	ASW7	ASW8	SW7	SW8	S4	SW28	S16T	SW40T
SO_4^{2-} (mg/l)	1440	1410	1560	1620	1410	1740	1410	1830	1560	1530	1710	1740	1380	1650	1350	1800
PO_4^{3-} (mg/l)	2	1.98	1.26	1.08	0.9	1.01	0.9	0.81	2.7	1.34	1.16	1.13	0.86	0.86	0.32	1.01
NH_4^+ (mg/l)	0.93	1.58	0.74	0.79	0.37	0.65	0.37	0.88	1.11	0.88	0.83	0.69	0.41	0.79	0.41	0.79
O/G (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	<0.001	<0.001	<0.001
THC (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	<0.001	<0.001	<0.001
TPH (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	<0.001	<0.001	<0.001
PAH (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	<0.001	<0.001	<0.001
BTEX (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	<0.001	<0.001	<0.001
Ni (mg/l)	0.116	0.391	0.257	0.291	0.139	0.221	0.148	0.212	0.184	0.127	0.195	0.148	0.196	0.186	0.107	0.139
Fe (mg/l)	0.029	0.141	0.085	0.058	0.118	0.047	0.114	0.052	0.125	0.057	0.061	0.081	0.104	0.028	0.079	0.097
Pb (mg/l)	0.853	0.671	0.327	0.382	0.293	0.322	0.217	0.266	0.546	0.195	0.335	0.613	0.338	0.283	<0.001	0.224
Cu (mg/l)	0.021	0.016	0.054	0.045	0.041	0.017	0.011	0.031	0.021	0.019	0.062	0.055	0.049	0.044	<0.001	0.039
Cr (mg/l)	0.04	0.028	0.052	0.046	0.105	0.253	0.104	0.162	0.127	0.229	0.052	<0.001	0.098	0.19	0.117	0.142
Zn (mg/l)	0.025	0.079	0.038	0.039	0.047	0.022	0.043	0.038	0.106	0.013	0.047	0.059	0.017	0.031	0.023	0.015
Cd (mg/l)	<0.001	<0.001	0.024	0.041	0.035	0.041	0.022	0.036	0.082	0.023	0.029	<0.001	0.049	0.035	<0.001	0.043
Mn (mg/l)	<0.001	0.027	0.091	0.022	0.043	0.019	0.034	0.028	0.035	0.027	0.047	0.063	0.026	0.024	0.063	0.031
Ba (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	<0.01
Co (mg/l)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Hg (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	<0.001	<0.001	<0.001

		BLOCK D								BLOCK E						
	200m		500m		800m		1200 m		200m		500m		800m		1200 m	
Parameters	ASW5	ASW6	SW5	SW6	S3	SW27	S15T	SW39	ASW7	ASW8	SW7	SW8	S4	SW28	S16T	SW40T
V (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	<0.001	<0.001	<0.001
K (mg/l)	364	350	314	337	351	382	348	336	349	356	365	353	359	372	356	361
Na (mg/l)	10027	10083	10051	10064	10189	10115	9782	10012	9985	10051	10301	10012	10218	10023	10162	10047
Mg (mg/l)	1027	1032	1223	1267	1195	1296	1127	1231	1211	1023	1215	1182	1410	1262	1192	1247
Ca (mg/l)	318	324	428	434	407	425	429	402	323	312	427	418	428	423	411	411
HUF (cfu/ml)	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL
HUB (cfu/ml) x 10^2	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	0.04X102	NIL	NIL	NIL	NIL
THB (cfu/ml) x 10^2	1.54	1.89	2.05	2.302	1.46	1.53	2.17	2.03	2.41	2.02	2.15	2	1.49	1.7	1.92	2.66
THF (cfu/ml) x 10^2	0.96	1.08	1.18	1.34	0.62	0.68	1.1	1.04	1.32	1.17	1.52	1.21	0.7	0.08	0.09	1.17
SRB (cfu/ml) x 10^3	1.22	1.4	1.57	1.32	1.75	1.38	1.22	1.75	1.33	1.12	1.33	1.27	1.34	1.58 x103	1.2	1.38
Coliforms	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 2.2.2: Detailed results for Surface water physicochemical and microbiological measurements in the JK Field during wet season Contd.

	BLOCK H								BLOCK C (mini cluster)							
	200m		500m		800m		1200 m		200m		500m		800m		1200 m	
Parameters	ASW15	ASW16	SW15	SW16	S8	SW32	S20T	SW44T	ASW3	ASW4	SW3	SW4	S2	SW26	S14T	SW38T
Temp. (°C)	27.2	26.9	26.3	27.6	26.8	27.3	26.9	27.8	28.3	28.3	28.4	27.3	27.4	26.8	28.2	27
PH	8.39	8.45	8.36	8.61	8.4	8.36	8.42	8.49	8.57	8.32	8.55	8.41	8.54	8.32	8.43	8.44
EC (µS/cm)	37300	42500	41900	32100	40900	35890	39200	31800	40200	39900	40700	39700	40500	40900	38500	41200
Turb. (NTU)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DO (mg/l)	5.9	6	6	6.1	5.9	5.9	5.9	6.1	6	5.9	5.9	6	6	5.9	5.9	6
TDS (mg/l)	26110	29750	25140	27470	28630	25123	27440	22260	28140	27930	28490	27790	28350	28630	26950	28840
Cl^- (mg/l)	14938	17011	16756	12865	16358	14427	15705	12808	16074	15960	16273	15904	16216	16358	15392	16500
Alkalinity (mg/l)	12	12	16	8	8	16	16	16	12	12	16	12	12	12	16	12
Colour (mg/l)	0.01	0.01	0	0	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0	0.02	0.01
TSS (mg/l)	20	22	22	20	18	22	20	22	18	22	26	22	18	22	22	24
COD (mg/l)	168	170	180	165	175	186	188	180	172	168	164	170	170	172	176	182
BOD (mg/l)	0.9	0.6	1.2	0.5	0.7	0.9	1.1	0.8	1.1	1.4	0.9	0.6	0.8	0.9	0.5	1.9
NO_3^- (mg/l)	1.1	0.9	1.7	1.4	1.1	1.5	0.5	0.8	0.8	1.9	1.7	1.9	0.5	1.6	1.3	1.3
$N0_2^-$ (mg/l)	0.59	0.81	1.25	1.03	0.81	1.11	0.37	0.59	0.59	1.4	1.25	1.4	0.37	1.18	0.96	1.11
SO_4^{2-} (mg/l)	1290	1440	1500	1470	1260	1710	1500	1620	1590	1500	1620	1590	1350	1590	1470	1770
PO_4^{3-} (mg/l)	0.88	0.99	1.08	1.05	0.56	0.96	0.96	1.13	2	2.9	1.12	1.15	0.59	1.32	0.92	0.94

	BLOCK H								BLOCK C (mini cluster)							
	200m		500m		800m		1200m		200m		500m		800m		1200m	
Parameters	ASW15	ASW16	SW15	SW16	S8	SW32	S20T	SW44T	ASW3	ASW4	SW3	SW4	S2	SW26	S14T	SW38T
NH_4^+ (mg/l)	0.37	0.51	0.88	0.79	0.51	0.69	0.23	0.37	0.37	0.88	0.79	0.88	0.23	0.74	0.6	0.69
O/G (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	<0.001	<0.001	<0.001
THC (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	<0.001	<0.001	<0.001
TPH (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	<0.001	<0.001	<0.001
PAH (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	<0.001	<0.001	<0.001
BTEX (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	<0.001	<0.001	<0.001
Ni (mg/l)	0.422	0.185	0.153	0.042	0.194	0.096	0.153	0.129	0.208	0.082	0.198	0.215	0.211	0.113	0.248	0.219
Fe (mg/l)	0.042	0.025	0.062	0.053	0.117	0.112	0.192	0.039	0.134	0.014	0.045	0.071	0.143	0.039	0.121	0.092
Pb (mg/l)	0.295	0.194	0.297	0.564	0.296	0.318	0.284	0.219	0.049	0.138	0.183	0.226	0.341	0.242	<0.001	0.212
Cu (mg/l)	0.022	0.012	0.016	0.044	0.053	0.053	0.052	0.035	0.041	0.039	0.019	0.013	0.028	0.011	0.011	0.042
Cr (mg/l)	<0.001	<0.001	0.227	0.114	0.034	0.191	0.182	0.122	0.089	<0.001	0.112	0.038	0.043	0.219	0.039	0.113
Zn (mg/l)	0.049	0.015	0.064	0.082	0.018	0.094	0.015	0.027	0.024	<0.001	0.038	0.042	0.031	0.018	0.01	0.022
Cd (mg/l)	0.008	0.048	0.031	0.024	0.027	0.061	0.021	0.042	0.036	0.029	0.026	0.053	0.028	0.032	<0.001	0.028
Mn (mg/l)	<0.001	0.036	0.039	0.051	0.039	0.035	0.036	0.025	0.021	0.127	0.037	0.063	0.027	0.038	0.043	0.044
Ba (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	<0.01
Co (mg/l)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Hg (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	<0.001	<0.001	<0.001
V (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	<0.001	<0.001	<0.001

	BLOCK H								BLOCK C (mini cluster)							
	200m		500m		800m		1200 m		200m		500m		800m		1200 m	
Parameters	ASW15	ASW16	SW15	SW16	S8	SW32	S20T	SW44T	ASW3	ASW4	SW3	SW4	S2	SW26	S14T	SW38T
K (mg/l)	323	352	357	358	374	363	349	382	348	325	371	362	356	353	382	336
Na (mg/l)	10134	10025	10234	10162	10105	10012	10119	10015	9829	10215	10118	10024	10137	10021	9827	9987
Mg (mg/l)	1025	1063	1214	1244	1264	1229	1210	1219	1014	1033	1239	1216	1242	1227	1261	1228
Ca (mg/l)	334	328	427	431	413	429	418	409	327	324	414	424	422	419	418	412
HUF (cfu/ml)	NIL	NIL	NIL	0.02X102	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL
HUB (cfu/ml) x 10^2	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	0.01X102	NIL	NIL
THB (cfu/ml) x 10^2	1.8	1.67	1.83	1.88	1.78	1.3	1.55	2.31	1.45	1.16	1.84	2.11	1.61	1.95	1.48	1.7
THF (cfu/ml) x 10^2	0.09	0.06	0.09	0.084	0.99	0.08	0.06	1.17	0.07	0.06	1.06	1.07	0.69	0.91	0.52	0.07
SRB (cfu/ml) x 10^3	1.3	1.57	1.57	1.82	1.52	1.32	1.17	1.33	1.03	1.13	1.53	1.78	1.83	1.53	1.37	1.83
Coliforms	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 2.2.2: Detailed results for Surface water physicochemical and microbiological measurements in the JK Field during wet season Contd.

	BLOCK F								BLOCK G											
	200m		500m		800m		1200m		200m				500m		800m				1200m	
Parameters	ASW9	ASW10	SW9	SW10T	S5	SW29	S17T	SW41T	ASW11	ASW12T	ASW12M	ASW12B	SW11T	SW12	S6T	S6M	S6B	SW30	S18	SW42T
Temp. (°C)	26.8	27.2	26.9	27.3	27.4	26.8	27.6	27.4	27	27	26.8	26.3	27.1	27.3	27.9	27.1	26.3	27.3	27	26.8
PH	8.36	8.26	8.2	8.38	8.46	8.42	8.33	8.39	8.16	8.36	8.38	8.41	8.26	8.21	8.39	8.36	8.45	8.1	8.24	8.33
EC (µS/cm)	35600	36400	35300	39400	36700	34500	35200	35900	33270	30600	34100	37390	31460	32320	30100	33400	37900	32510	30240	30100
Turb. (NTU)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DO (mg/l)	6	5.9	5.8	6	5.9	6	5.9	5.8	5.8	6	4.5	3.9	5.9	6	6	4.5	4	5.9	6	5.9
TDS (mg/l)	24920	25480	24710	27580	25690	24150	24640	25130	23289	21420	23870	26173	22022	22624	21070	23380	26530	22757	21168	21070
Cl^- (mg/l)	14256	14569	14114	15762	14783	13802	14084	14370	13319	12240	13660	14966	12581	12922	12041	13376	15165	13007	12098	12070
Alkalinity (mg/l)	8	8	12	12	8	12	16	16	12	12	12	8	8	8	16	12	12	12	12	12
Colour (mg/l)	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0	0.01	0.01	0.01	0	0.01	0	0	0	0.01	0	0.02	0.01
TSS (mg/l)	20	20	26	20	18	20	22	22	18	20	26	34	22	20	20	28	32	22	20	20
COD (mg/l)	166	184	162	170	182	158	172	170	166	160	162	168	166	186	172	174	178	160	176	200
BOD (mg/l)	2.2	1.5	0.6	0.8	0.4	0.6	0.4	0.9	0.8	1	0.6	1	0.8	1.1	1.1	0.8	1.1	1.5	1	0.7
NO_3^- (mg/l)	1.8	2.1	1.2	1.5	1	1.5	1.3	0.9	0.9	0.8	1.3	0.9	1.8	2.4	1.9	1.4	1.3	1.3	1.4	1.1
$N0_2^-$ (mg/l)	1.33	1.55	0.88	1.11	0.74	1.11	0.96	0.66	0.66	0.59	0.59	0.96	1.33	1.77	1.4	1.03	0.96	1.96	1.03	0.81

	BLOCK F								BLOCK G											
	200m		500m		800m		1200m		200m				500m		800m				1200m	
Parameters	ASW9	ASW10	SW9	SW10T	S5	SW29	S17T	SW41T	ASW11	ASW12T	ASW12M	ASW12B	SW11T	SW12	S6T	S6M	S6B	SW30	S18	SW42T
SO_4^{2-} (mg/l)	1620	1200	1590	1500	1350	1740	1770	1740	1380	1260	1620	1680	1470	1410	1440	1650	1740	1680	1620	1500
PO_4^{3-} (mg/l)	1.11	0.94	1.24	1.08	0.93	0.94	0.18	0.99	0.73	0.48	0.72	1.02	1.03	1.18	0.81	0.27	0.18	0.78	0.58	1.01
NH_4^+ (mg/l)	0.83	0.97	0.55	0.69	0.46	0.69	0.6	0.41	0.41	0.37	0.37	0.6	0.65	0.83	0.88	0.65	0.6	0.6	0.65	0.51
O/G (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	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
THC (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	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
TPH (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	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
PAH (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	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
BTEX (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	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Ni (mg/l)	0.176	0.295	0.215	0.039	0.175	0.195	0.171	0.169	0.258	0.182	0.216	0.229	0.171	0.032	<0.001	0.163	0.21	0.372	0.192	0.063
Fe (mg/l)	0.014	0.106	0.038	0.043	0.094	0.042	0.094	0.052	0.075	0.042	0.113	0.138	0.021	0.117	0.443	0.129	0.138	0.069	0.112	0.098
Pb (mg/l)	0.212	0.352	0.205	0.082	0.253	0.324	0.311	0.259	0.111	0.214	0.254	0.208	0.318	0.327	0.156	0.472	0.48	0.261	0.115	0.311
Cu (mg/l)	0.032	0.034	0.021	0.051	0.032	0.065	0.011	0.026	0.015	0.021	0.029	0.046	0.043	0.029	0.025	0.081	0.089	0.014	0.011	0.062
Cr (mg/l)	0.018	0.011	0.025	0.251	0.212	0.174	0.103	0.056	<0.001	0.021	0.041	0.038	0.224	0.238	0.033	0.12	0.168	0.236	0.138	0.019
Zn (mg/l)	0.027	0.019	0.059	0.121	0.036	0.024	0.051	0.013	0.018	0.101	0.112	0.129	0.084	0.115	0.109	0.121	0.139	0.019	0.023	0.029
Cd (mg/l)	0.016	0.023	0.013	0.063	0.121	0.031	0.018	0.031	0.109	0.078	0.05	0.056	0.036	0.052	0.013	0.006	0.004	0.009	0.112	0.029
Mn (mg/l)	0.079	<0.001	0.049	0.053	0.082	0.011	0.034	0.026	0.042	0.019	0.037	0.069	0.026	0.054	0.023	0.029	0.042	0.015	0.062	0.021

	BLOCK F								BLOCK G											
	200m		500m		800m		1200m		200m				500m		800m				1200m	
Parameters	ASW9	ASW10	SW9	SW10T	S5	SW29	S17T	SW41T	ASW11	ASW12T	ASW12M	ASW12B	SW11T	SW12	S6T	S6M	S6B	SW30	S18	SW42T
Ba (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	<0.01	<0.01	<0.01	<0.01	<0.01
Co (mg/l)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Hg (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	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
V (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	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
K (mg/l)	375	327	363	362	352	365	369	329	301	329	327	318	328	325	336	358	353	377	375	353
Na (mg/l)	10026	10141	10031	9934	10212	10011	10151	9967	9983	9991	10017	10041	9985	9967	10185	10161	9915	10131	9925	10018
Mg (mg/l)	1018	1132	1229	1127	1117	1241	1206	1212	1026	1114	1182	1154	1218	1195	1257	1174	1193	1216	1215	1221
Ca (mg/l)	324	357	428	408	409	427	414	404	346	312	326	318	415	411	439	412	418	421	415	411
HUF (cfu/ml)	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL
HUB (cfu/ml) x 10^2	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	0.04X 102	NIL	0.01X 102	NIL	0.01X 102
THB (cfu/ml) x 10^2	2.13	1.78	1.62	1.69	1.5	2.56	2.01	2.71	1.53	2.11	2.01	2.3	1.99	1.75	1.74	1.95	1.6	1.47	2.41	1.89
THF (cfu/ml) x 10^2	1.1	0.08	0.88	0.68	0.07	1.16	1.28	1.13	1.03	0.09	0.09	1.01	0.08	0.69	0.06	0.09	0.06	0.01	1.28	1.02

	BLOCK F								BLOCK G											
	200m		500m		800m		1200m		200m				500m		800m				1200m	
Parameters	ASW9	ASW10	SW9	SW10T	S5	SW29	S17T	SW41T	ASW11	ASW12T	ASW12M	ASW12B	SW11T	SW12	S6T	S6M	S6B	SW30	S18	SW42T
SRB (cfu/ml) x 10^3	1.25	1.39	1.47	1.53	1.2	1.43	1.35	1.37	1.5	1.23	1.44	1.28	1.94	1.73	1.08	1.15	1.27	1.33	1.49	1.37
Coliforms	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 2.2.2: Detailed results for Surface water physicochemical and microbiological measurements in the JK Field during wet season Contd.

	BLOCK I										BLOCK A							
	200m		500m				800m		1200m		200m		500m		800m		1200m	
Parameters	ASW19	ASW20	SW19T	SW19M	SW19B	SW20	S10	SW34	S22T	SW46T	ASW1	ASW2	SW1	SW2	S1	SW25	S13T	SW37T
Temp. (^oC)	27.9	26.1	27.1	26.2	26.2	27.7	26.7	27.6	26.5	28	27.8	27.8	27.2	28.2	28.1	28.1	27.7	27.1
PH	8.33	8.47	8.36	8.42	8.5	8.35	8.27	8.32	8.41	8.39	8.43	8.27	8.38	8.54	8.36	8.42	8.41	8.37
EC (µS/cm)	37100	39800	39600	40100	43300	28800	38300	38200	37300	37300	40200	39300	40500	39900	40100	36800	37600	39600
Turb. (NTU)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DO (mg/l)	5.9	5.9	6	4.5	3.7	5.9	5.9	6	6	5.9	6	5.8	5.9	6	5.9	5.9	5.9	5.9
TDS (mg/l)	25970	27860	27720	28000	30310	27160	26110	26740	26110	26110	28140	27510	28350	27930	28070	25760	26320	27720
Cl^- (mg/l)	14853	15932	15847	16017	17324	15534	15307	15279	14910	14938	16074	15733	16216	15960	16046	14711	15052	15847
Alkalinity (mg/l)	8	8	12	8	12	12	8	8	12	12	16	8	12	12	16	12	16	12

	BLOCK I										BLOCK A							
	200m		500m				800m		1200m		200m		500m		800m		1200m	
Parameters	ASW19	ASW20	SW19T	SW19M	SW19B	SW20	S10	SW34	S22T	SW46T	ASW1	ASW2	SW1	SW2	S1	SW25	S13T	SW37T
Colour (mg/l)	0.01	0	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	0.01
TSS (mg/l)	20	18	20	20	32	24	22	22	20	20	22	10	20	24	22	20	20	24
COD (mg/l)	178	165	180	182	184	166	170	160	188	178	164	156	170	176	175	170	164	168
BOD (mg/l)	1.3	0.9	0.6	0.5	0.7	1.1	0.6	0.7	0.4	1.1	0.6	0.7	1.6	1.2	1.1	1	0.6	1.5
NO_3^- (mg/l)	1.3	1	1.5	1.2	1.3	1.6	0.8	1.9	0.6	0.6	1.9	1.5	1.5	1.8	0.7	1.3	0.8	1.6
$N0_2^-$ (mg/l)	0.96	0.74	1.11	0.88	0.96	1.18	0.59	1.4	0.44	0.44	1.4	1.11	1.11	1.33	0.51	0.96	0.59	1.18
SO_4^{2-} (mg/l)	1860	1590	1590	1680	1800	1650	1350	1560	1770	1560	1410	1470	1500	1470	1440	1770	1410	1710
PO_4^{3-} (mg/l)	0.84	0.81	1.06	1.32	1.2	1.03	0.67	0.93	0.24	1.13	2.12	2.61	0.85	0.95	0.35	1.02	0.9	0.73
NH_4^+ (mg/l)	0.6	0.46	0.74	0.55	0.6	0.74	0.37	0.88	0.27	0.27	0.88	0.69	0.69	0.83	0.32	0.6	0.37	0.74
O/G (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	<0.001	<0.001	<0.001	<0.001	<0.001
THC (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	<0.001	<0.001	<0.001	<0.001	<0.001
TPH (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	<0.001	<0.001	<0.001	<0.001	<0.001
PAH (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	<0.001	<0.001	<0.001	<0.001	<0.001
BTEX (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	<0.001	<0.001	<0.001	<0.001	<0.001
Ni (mg/l)	0.207	0.282	0.172	0.179	0.231	0.105	0.361	0.084	0.119	0.115	0.179	0.152	0.211	0.231	0.186	0.147	0.225	0.243
Fe (mg/l)	0.042	0.016	0.051	0.063	0.105	0.039	0.039	0.043	0.065	0.043	0.021	0.037	0.058	0.062	0.091	0.127	0.057	0.045

	BLOCK I										BLOCK A							
	200m		500m				800m		1200m		200m		500m		800m		1200m	
Parameters	ASW19	ASW20	SW19T	SW19M	SW19B	SW20	S10	SW34	S22T	SW46T	ASW1	ASW2	SW1	SW2	S1	SW25	S13T	SW37T
Pb (mg/l)	0.271	0.286	0.213	0.229	0.325	0.182	<0.001	0.326	0.238	0.229	0.191	0.191	0.312	0.291	0.119	0.385	0.256	<0.001
Cu (mg/l)	0.021	0.013	0.011	0.049	0.049	0.044	0.028	0.03	0.033	0.058	0.05	0.029	0.014	0.016	0.056	0.014	0.015	0.038
Cr (mg/l)	0.032	0.028	<0.001	0.024	0.053	0.257	<0.001	0.226	0.197	0.025	<0.001	<0.001	0.095	0.034	0.119	0.155	0.098	0.154
Zn (mg/l)	0.022	0.049	0.081	0.097	0.119	0.029	0.039	0.011	0.024	0.011	0.011	0.003	0.056	0.076	0.016	0.025	0.027	0.097
Cd (mg/l)	0.029	0.031	0.034	0.039	0.048	0.031	0.099	0.051	0.013	0.028	0.14	0.027	0.033	0.017	0.032	0.027	0.031	0.021
Mn (mg/l)	0.019	0.038	0.029	0.039	0.052	0.044	0.027	0.038	0.02	0.031	0.031	0.004	0.033	0.048	0.018	0.021	0.038	0.032
Ba (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	<0.01	<0.01	<0.01
Co (mg/l)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Hg (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	<0.001	<0.001	<0.001	<0.001	<0.001
V (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	<0.001	<0.001	<0.001	<0.001	<0.001
K (mg/l)	335	344	374	396	396	346	353	353	349	339	352	351	368	372	319	361	331	363
Na (mg/l)	10093	9863	9919	9947	10121	9913	9961	10067	9955	10095	10123	10015	10105	9957	10102	10012	9722	10024
Mg (mg/l)	1012	1038	1265	1269	1278	1214	1142	1241	1232	1236	1136	1131	1183	1187	1134	1226	1262	1218
Ca (mg/l)	351	345	432	441	459	403	419	422	429	412	312	324	415	407	412	412	415	409
HUF (cfu/ml)	NIL	0.01X102	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL

	BLOCK I										BLOCK A							
	200m		500m				800m		1200 m		200m		500 m		800 m		1200 m	
Parameters	ASW19	ASW20	SW19T	SW19M	SW19B	SW20	S10	SW34	S22T	SW46T	ASW1	ASW2	SW1	SW2	S1	SW25	S13T	SW37T
HUB (cfu/ml) x 10^2	NIL	0.03X102	NIL	NIL	NIL	NIL	0.01X102	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	0.08X102
THB (cfu/ml) x 10^2	1.83	1.92	1.8	2.16	1.92	1.92	1.83	2.2	1.93	2.1	1.97	0.17	2.09	2.32	1.74	1.8	2.5	1.58
THF (cfu/ml) x 10^2	0.08	0.06	0.07	1.17	1.32	0.94	0.08	1.1	0.07	1.22	1.01	0.09	1.28	1.1	0.08	0.08	1.31	1.05
SRB (cfu/ml) x 10^3	1.5	1.37	1.55	1.31	1.35	1.53	1.5	1.37	1.12	1.73	1.18	1.24	1.4	1.03	1.52	1.21	1.41	1.34
Coliforms	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 2.2.2: Detailed results for Surface water physicochemical and microbiological measurements in the JK Field during wet season Contd.

	BLOCK J								BLOCK GS							
	200m		500m		800m		1200 m		200m		500m		800m		1200 m	
Parameters	ASW21	ASW22	SW21	SW22	S11	SW35	S23T	SW47T	ASW13	ASW14	SW13	SW14	S7	SW31	S19T	SW43T
Temp. (°C)	27.2	27.2	27.6	27.4	27.4	27.6	27.2	27.6	28.2	27.6	27.3	28	27.1	27.7	28.9	27.6
PH	8.52	8.65	8.58	8.39	8.45	8.61	8.41	8.57	8.46	8.65	8.38	8.41	8.5	8.38	8.56	8.35
EC (µS/cm)	37500	36700	34600	35200	34700	35600	34800	35800	34600	33400	33700	33900	37700	34100	31900	33200
Turb. (NTU)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

	BLOCK J								BLOCK GS							
	200m		500m		800m		1200m		200m		500m		800m		1200m	
Parameters	ASW21	ASW22	SW21	SW22	S11	SW35	S23T	SW47T	ASW13	ASW14	SW13	SW14	S7	SW31	S19T	SW43T
DO (mg/l)	5.9	6	5.9	6	5.9	6.2	6.1	6	6.2	5.5	6.1	5.9	5.9	6	5.9	5.9
TDS (mg/l)	26250	25690	24220	34640	24290	24920	24360	25060	24220	23380	23590	23730	22890	23870	22330	23240
Cl^- (mg/l)	15080	14796	13916	14114	13944	14285	13972	14370	13887	13433	13490	13603	13120	13660	12780	13291
Alkalinity (mg/l)	12	12	12	12	16	12	12	16	8	12	8	14	12	12	16	12
Colour (mg/l)	0	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0	0	0	0.01	0.01	0.01
TSS (mg/l)	24	20	20	18	22	24	22	20	18	26	18	20	16	24	22	18
COD (mg/l)	174	178	174	166	182	188	172	170	172	170	178	172	176	174	174	174
BOD (mg/l)	1.4	0.8	3.4	1.1	0.8	0.4	0.9	0.8	1.2	0.7	1.6	0.9	1	1	0.5	0.6
NO_3^- (mg/l)	0.9	0.8	1.3	1.2	1	1.8	0.4	0.8	0.7	0.8	2	1.9	0.9	1.6	0.8	0.7
$N0_2^-$ (mg/l)	0.66	0.59	0.96	0.88	0.74	1.33	0.29	0.59	0.66	0.51	1.48	1.4	0.66	1.18	0.59	0.51
SO_4^{2-} (mg/l)	1650	1800	1740	1680	1410	1650	1410	1380	1320	1440	1500	1590	1350	1590	1500	840
PO_4^{3-} (mg/l)	1.21	0.74	0.96	0.73	0.85	1.02	0.76	0.37	0.93	0.78	1.1	1.13	0.39	1.05	0.76	0.93
NH_4^+ (mg/l)	0.41	0.37	0.61	0.55	0.46	0.83	0.18	0.37	0.41	0.32	1.11	0.93	0.41	0.74	0.37	0.32
O/G (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	<0.001	<0.001	<0.001
THC (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	<0.001	<0.001	<0.001
TPH (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	<0.001	<0.001	<0.001

	BLOCK J								BLOCK GS							
	200m		500m		800m		1200m		200m		500m		800m		1200m	
Parameters	ASW21	ASW22	SW21	SW22	S11	SW35	S23T	SW47T	ASW13	ASW14	SW13	SW14	S7	SW31	S19T	SW43T
PAH (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	<0.001	<0.001	<0.001
BTEX (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	<0.001	<0.001	<0.001
Ni (mg/l)	0.41	0.491	0.203	0.193	0.229	0.113	0.253	0.109	0.185	0.173	0.229	0.082	0.355	0.439	0.181	0.134
Fe (mg/l)	0.172	0.32	0.061	0.029	0.101	0.117	0.073	0.057	0.096	0.065	0.44	0.037	0.153	0.046	0.084	0.092
Pb (mg/l)	0.185	0.485	0.232	0.341	0.183	0.285	0.005	0.123	0.319	0.27	0.294	0.321	0.397	0.284	0.182	0.295
Cu (mg/l)	0.036	0.011	0.062	0.045	0.049	0.066	0.081	0.045	0.058	0.021	0.014	0.05	0.059	0.042	0.023	0.023
Cr (mg/l)	0.043	0.033	0.164	0.188	<0.001	0.172	0.12	0.065	0.113	0.02	0.241	0.191	0.157	0.184	0.224	<0.001
Zn (mg/l)	<0.001	<0.001	0.051	0.032	0.042	0.038	0.056	0.022	0.027	0.031	0.06	0.029	0.007	0.056	0.013	0.013
Cd (mg/l)	0.028	0.032	0.028	0.019	0.049	0.037	0.022	0.044	0.011	<0.001	0.039	0.064	0.058	0.025	0.022	0.063
Mn (mg/l)	0.063	0.041	0.036	0.043	0.026	0.025	0.071	0.027	0.024	0.021	0.101	0.037	0.027	0.023	0.054	0.035
Ba (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	<0.01
Co (mg/l)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Hg (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	<0.001	<0.001	<0.001
V (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	<0.001	<0.001	<0.001
K (mg/l)	321	343	365	342	352	347	367	396	349	305	337	343	363	371	368	359
Na (mg/l)	10119	9982	10112	10059	9694	10028	9440	10096	10029	10015	10141	10113	9528	10019	9718	10215
Mg (mg/l)	1052	1123	1223	1236	1218	1198	1237	1213	1009	1016	1215	10062	1129	1245	1229	1242
Ca (mg/l)	321	349	421	428	427	421	409	408	315	309	427	418	423	422	434	412
HUF (cfu/ml)	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL

	BLOCK J								BLOCK GS							
	200m		500m		800m		1200 m		200m		500m		800m		1200 m	
Parameters	ASW21	ASW22	SW21	SW22	S11	SW35	S23T	SW47T	ASW13	ASW14	SW13	SW14	S7	SW31	S19T	SW43T
HUB (cfu/ml) x 10^2	NIL	0.07X102	NIL	0.03X102	NIL	0.06X102	NIL	NIL	NIL	0.09X102	NIL	NIL	NIL	NIL	NIL	NIL
THB (cfu/ml) x 10^2	2.6	2.33	2.2	1.82	2.44	1.52	1.9	2.13	1.7	1.91	2.01	1.94	1.9	1.28	1.89	1.78
THF (cfu/ml) x 10^2	1.4	1.26	1.09	1.11	1.22	0.09	0.09	1.32	0.76	1.12	1.06	0.09	0.09	0.06	0.09	1.33
SRB (cfu/ml) x 10^3	1.33	1.24	1.7	1.23	1.3	1.84	1.42	1.35	1.33	1.43	1.52	1.81	1.32	1.35	1.3	1.33
Coliforms	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 2.2.2: Detailed results for Surface water physicochemical and microbiological measurements in the JK Field during wet season Contd.

	BLOCK K								BLOCK HE										
	200m		500 m		800 m		1200m		200m		500 m		800 m		1200 m				
Parameters	ASW23	ASW24	SW23	SW24	S12	SW36	S24T	SW48T	ASW17	ASW18	SW17	SW18T	S9	SW33	S21T	SW45T	CONTL 1 TP	CONTL 2 TP	CONTL 3 TP
Temp. (°C)	26.5	26.5	26.5	26.8	26.7	26.2	26.4	27.6	29.4	28.5	29.3	28.1	28	28.8	28.9	28.1	27.5	28.1	28.1
PH	8.33	8.15	8.65	8.07	8.11	8.62	8.14	8.44	8.52	8.39	8.43	8.41	8.12	8.59	8.35	8.21	8.24	8.52	8.51
EC (µS/cm)	36500	37200	36300	29580	30500	36700	31100	33200	38200	34400	32200	34300	34100	31700	34100	27150	40400	38700	38300
Turb. (NTU)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.3

	BLOCK K								BLOCK HE										
	200m		500m		800m		1200m		200m		500m		800m		1200m				
Parameters	ASW23	ASW24	SW23	SW24	S12	SW36	S24T	SW48T	ASW17	ASW18	SW17	SW18T	S9	SW33	S21T	SW45T	CONTL1 TP	CONTL2 TP	CONTL3 TP
DO (mg/l)	5.9	6	5.9	5.9	6	6	5.9	5.8	6.1	5.9	5.9	5.9	6.1	6	5.8	5.8	6	5.9	5.9
TDS (mg/l)	25550	26040	25410	20706	21350	25690	21770	23240	19200	17200	16100	17200	17400	15900	23870	13580	28070	27090	36810
Cl^- (mg/l)	14626	14910	14540	11842	12212	14711	12467	13291	15364	13802	12922	13745	13717	12723	13688	11019	16046	15478	15307
Alkalinity (mg/l)	12	12	8	12	12	12	16	12	12	12	16	12	8	33	16	16	16	16	8
Colour (mg/l)	0.01	0	0	0	0.01	0.01	0.01	0.01	0.02	0	0.01	0.01	0.01	0	0.01	0.01	0.01	0	0.01
TSS (mg/l)	22	20	24	22	22	22	18	22	20	18	22	24	24	24	22	20	22	22	20
COD (mg/l)	170	180	174	172	170	170	176	186	180	182	160	166	166	170	170	194	201	182	188
BOD (mg/l)	2.2	0.6	1.6	1.2	0.8	1.3	1.3	0.4	0.8	2.1	0.9	1.3	0.6	0.3	1.1	1.5	0.8	1.3	1
NO_3^- (mg/l)	1.1	0.8	1.4	1.2	1	1.8	0.7	0.8	0.8	0.8	1.8	1.6	0.9	1.3	0.7	0.8	0.9	0.6	0.9
$N0_2^-$ (mg/l)	0.81	0.59	1.03	0.88	0.74	1.33	0.51	0.59	0.66	0.59	1.33	1.18	0.66	0.96	0.51	0.59	0.48	0.59	0.51
SO_4^{2-} (mg/l)	1440	1740	1800	1860	1350	1650	1470	1440	1470	1590	1650	1560	1320	1650	1470	1500	1442	1500	1380
PO_4^{3-} (mg/l)	0.81	0.99	0.86	1.14	0.91	0.86	0.71	0.89	0.93	1.04	1.03	1.07	0.71	0.81	1.1	0.86	1.2	0.85	0.83
NH_4^+ (mg/l)	0.51	0.37	0.65	0.55	0.46	0.83	0.32	0.37	0.41	0.37	0.65	0.83	0.41	0.6	0.32	0.37	0.37	0.28	0.28
O/G (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	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
THC (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	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

	BLOCK K								BLOCK HE										
	200m		500m		800m		1200m		200m		500m		800m		1200m				
Parameters	ASW23	ASW24	SW23	SW24	S12	SW36	S24T	SW48T	ASW17	ASW18	SW17	SW18T	S9	SW33	S21T	SW45T	CONTL1 TP	CONTL2 TP	CONTL3 TP
TPH (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	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
PAH (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	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
BTEX (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	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Ni (mg/l)	0.217	0.205	0.206	0.313	0.214	0.181	0.169	0.116	0.293	0.211	0.053	0.082	0.186	0.113	0.187	0.028	0.258	0.173	0.125
Fe (mg/l)	0.139	0.121	0.047	0.082	0.084	0.092	0.025	0.047	0.064	0.085	0.092	0.101	0.053	0.049	0.204	0.369	0.137	0.127	0.122
Pb (mg/l)	0.218	0.311	0.392	0.286	0.249	0.318	0.027	0.114	0.252	0.263	0.229	0.018	0.002	0.299	0.309	<0.001	0.102	0.138	<0.001
Cu (mg/l)	0.02	0.022	0.051	0.019	0.047	0.042	0.67	0.03	0.039	0.019	0.028	0.015	0.017	0.027	0.026	0.057	0.029	0.039	0.022
Cr (mg/l)	0.017	0.024	0.043	0.202	0.173	0.158	0.206	0.016	0.028	0.113	0.206	0.082	<0.001	0.173	0.096	0.315	0.105	0.136	<0.001
Zn (mg/l)	0.029	0.022	0.011	0.038	0.016	0.015	0.037	0.021	0.029	0.018	0.053	0.025	0.054	0.023	0.038	<0.001	0.016	0.018	0.016
Cd (mg/l)	0.041	0.027	0.023	0.036	0.012	0.026	0.022	0.028	0.021	0.056	0.033	0.02	0.013	0.038	0.107	0.025	0.005	0.011	0.011
Mn (mg/l)	0.054	0.018	0.061	0.018	0.045	0.034	0.012	0.027	0.019	0.043	0.036	0.019	0.014	0.027	0.005	0.042	0.035	0.047	0.035
Ba (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	<0.01	<0.01	<0.01	<0.01
Co (mg/l)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Hg (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	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
V (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	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
K (mg/l)	361	395	341	353	347	374	356	349	368	371	349	354	351	342	375	355	364	353	372

	BLOCK K								BLOCK HE									
	200m		500m		800m		1200m		200m		500m		800m		1200m			
Parameters	ASW23	ASW24	SW23	SW24	S12	SW36	S24T	SW48T	ASW17	ASW18	SW17	SW18T	S9	SW33	S21T	SW45T	CONTL1 TP	CONTL2 TP	CONTL3 TP
Na (mg/l)	9959	1021	9948	10028	10091	10029	10211	10056	9569	10128	10241	10013	9869	10053	9915	10119	9963	9962	9892
Mg (mg/l)	1075	1097	1218	1224	1302	1227	1253	1213	1029	1022	1253	1262	1095	1218	1223	1219	1194	1224	1184
Ca (mg/l)	382	383	402	409	435	411	415	416	339	353	422	454	403	436	415	417	406	405	401
HUF (cfu/ml)	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	0.01X102	NIL	NIL	0.02X102	NIL
HUB (cfu/ml) x 10^2	NIL	0.02X102	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL
THB (cfu/ml) x 10^2	1.95	1.78	2.14	2.31	2.06	1.19	1.51	2.62	1.47	1.58	2.1	2.02	2.06	1.66	2.42	1.95	1.63	1.65	2.11
THF (cfu/ml) x 10^2	0.07	0.07	1.2	0.92	1.02	0.86	0.09	1.16	1.01	0.09	1.12	0.09	1.01	0.07	1.31	1.02	0.07	0.07	1.1
SRB (cfu/ml) x 10^3	1.13	1.4	1.33	1.44	1.57	1.51	1.53	1.34	1.41	1.35	1.37	1.73	1.43	1.42	1.13	1.48	1.47	1.5	1.33
Coliforms	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 2.2.3: Detailed results for Water column physicochemical and microbiological measurements in the JK Field during dry season

	Block D			Block E			Block E			Block H			Block H		
Parameters	S15T	S15M	S15B	S16T	S16M	S16B	SW40 T	SW40 M	SW40 B	S20T	S20M	S20B	SW44 T	SW44 M	SW44 B
Temp. (^oC)	28.3	27.6	27.1	27.2	27.4	27.1	28.3	27.9	27.4	28.3	27.9	27.6	28.2	27.7	27.4
PH	8.58	8.59	8.59	8.53	8.54	8.54	8.53	8.52	8.52	8.54	8.53	8.55	8.52	8.54	8.53
EC (µS/cm)	38000	44100	46300	38400	41100	44700	38600	45700	47000	38900	43600	43900	40500	42500	44900
Turb. (NTU)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DO (mg/l)	5.9	4.1	3.2	5.9	4.2	3.4	5.9	4.1	3.3	5.9	4.1	3.3	5.8	4.1	3.7
TDS (mg/l)	26612	28400	32412	26880	28770	31290	27022	31990	32900	27230	30520	30730	28350	29751	31430
Cl^- (mg/l)	13722	15925	16719	13393	16409	17125	13939	16503	16972	14032	13368	15029	14625	15347	16214
Alkalinity (mg/l)	16	16	14	16	12	10	16	14	16	16	12	12	16	16	12
Colour (mg/l)	0.01	0.01	0	0.01	0.01	0.02	0.01	0	0.01	0.01	0.01	0.01	0.01	0.01	0.01
TSS (mg/l)	20	24	32	24	36	32	18	16	20	20	30	24	26	22	24
COD (mg/l)	166	187	173	180	187	169	170	163	164	192	188	180	181	175	179
BOD (mg/l)	0.8	0.5	0.3	0.4	0.6	0.5	0.8	0.5	0.2	1.3	0.7	0.5	0.7	0.6	0.2
NO_3^- (mg/l)	1.2	1.4	0.8	0.9	0.7	1	0.9	1	1.4	1.4	1.6	0.9	1.2	0.8	0.8
$N0_2^-$ (mg/l)	3.94	4.51	2.63	2.96	2.29	3.28	2.96	3.38	4.59	4.59	5.25	2.95	3.94	2.63	2.63
SO_4^{2-} (mg/l)	784	786	690	640	650	710	638	671	681	862	768	760	681	741	782
PO_4^{3-} (mg/l)	0.48	0.4	0.32	0.38	0.35	0.28	0.38	0.32	0.3	0.42	0.44	0.38	0.38	0.46	0.54
NH_4^+ (mg/l)	0.56	0.65	0.38	0.44	0.34	0.46	0.43	0.47	0.65	0.66	0.76	0.48	0.56	0.37	0.36
O/G (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	<0.001	<0.001
THC (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	<0.001	<0.001
TPH (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	<0.001	<0.001
PAH (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	<0.001	<0.001
BTEX (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	<0.001	<0.001

	Block D			Block E			Block E			Block H			Block H		
Parameters	S15T	S15M	S15B	S16T	S16M	S16B	SW40 T	SW40 M	SW40 B	S20T	S20M	S20B	SW44 T	SW44 M	SW44 B
Ni (mg/l)	0.234	0.365	0.421	0.124	0.124	0.136	0.152	0.286	0.345	0.211	0.224	0.325	0.112	0.23	0.247
Fe (mg/l)	0.094	0.107	0.119	0.051	0.072	0.098	0.068	0.094	0.146	0.124	0.136	0.139	0.063	0.087	0.117
Pb (mg/l)	0.382	0.387	0.395	0.296	0.364	0.392	0.391	0.267	0.324	0.342	0.425	0.438	0.321	0.339	0.345
Cu (mg/l)	0.023	0.036	0.058	0.014	0.026	0.059	0.063	0.078	0.085	0.073	0.081	0.096	0.022	0.031	0.036
Cr (mg/l)	0.092	0.124	0.187	0.124	0.137	0.148	0.231	0.236	0.261	0.243	0.282	0.315	0.028	0.037	0.039
Zn (mg/l)	0.027	0.029	0.038	0.021	0.039	0.062	0.003	0.012	0.019	<0.001	0.058	0.076	0.034	0.044	0.048
Cd (mg/l)	0.031	0.045	0.051	0.033	0.058	0.073	0.046	0.062	0.079	0.028	0.043	0.052	0.061	0.065	0.068
Mn (mg/l)	0.027	0.039	0.063	0.027	0.049	0.081	0.054	0.061	0.064	<0.001	0.005	0.019	0.074	0.077	0.079
Ba (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
Co (mg/l)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Hg (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	<0.001	<0.001
V (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	<0.001	<0.001
K (mg/l)	375	385	387	386	387	390	368	360	366	370	386	345	372	376	379
Na (mg/l)	9864	10100	10105	10235	10011	10024	10023	10034	10046	9354	9427	9354	10231	10236	10348
Mg (mg/l)	1101	1243	1125	1240	1234	1248	1123	1230	1230	1198	1223	1232	1236	1240	1241
Ca (mg/l)	421	432	435	425	430	440	406	407	410	405	402	403	403	405	408
HUF (cfu/ml)	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL
HUB (cfu/ml) x 10^2	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL
THB (cfu/ml) x 10^2	2.13	1.82	1.93	2.12	1.82	1.72	2.28	1.97	2.01	2.28	1.82	1.73	2.28	1.97	2.01
THF (cfu/ml) x 10^2	1.21	1.33	1.14	1.19	1.11	1.02	1.32	8.2	1.33	1.28	1.02	1.11	1.32	8.2	1.33
SRB (cfu/ml) x 10^3	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Coliforms	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0

Appendix 2.2.3: Detailed results for Water column physicochemical and microbiological measurements in the JK Field during dry season Contd.

	Block C			Block C			Block F			Block F			Block G			Block G			Block G		
Parameters	S14T	S14M	S14B	SW38T	SW38M	SW38B	S17T	S17M	S17B	SW41T	SW41M	SW41B	SW11T	SW11M	SW11B	S6T	S6M	S6B	SW42T	SW42M	SW42B
Temp. (^oC)	27.3	26.9	26.5	28.5	28.3	28.1	29.4	28.9	27.6	28.6	28.1	27.8	28.2			30.2	29	28.7	28.9	28.3	27.7
PH	8.56	8.52	8.5	8.56	8.53	8.55	8.53	8.54	8.56	8.52	8.54	8.55	8.55			8.57	8.56	8.57	8.57	8.58	8.57
EC (µS/cm)	39500	41600	42100	39700	45900	48300	39800	40100	40300	39500	42000	47900	38400			40500	47600	48400	41100	43600	47200
Turb. (NTU)	0	0	0	0	0	0	0	0	0	0	0	0	0			0	0	0	0	0	0
DO (mg/l)	6	4.1	3.3	6	4.1	3.2	6	4.2	3.6	5.9	4.2	5.8	5.8			6.1	4.1	3.6	6	4.2	3.6
TDS (mg/l)	27650	29120	29740	27790	32130	33812	27862	28081	28214	27650	29400	33530	26880			28350	33321	33887	28770	30520	33047
Cl^- (mg/l)	13291	14160	15949	14336	16575	17442	13163	15157	15362	14264	15167	17297	14878			14336	14638	14463	14842	15744	17044
Alkalinity (mg/l)	16	14	12	12	14	12	16	12	12	16	12	14	14			16	16	14	12	16	14
Colour (mg/l)	0.02	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0	0	0.01	0.01			0	0	0.01	0.01	0	0.01
TSS (mg/l)	22	28	36	20	22	18	22	24	32	26	24	28	20			18	16	20	20	20	18
COD (mg/l)	175	169	172	184	168	149	175	167	165	177	201	199	165			180	183	189	205	188	176
BOD (mg/l)	0.6	0.3	0.3	0.6	0.3	0.1	0.7	0.3	0.3	0.9	0.5	0.3	0.6			0.7	0.5	0.3	0.5	0.2	0.2
NO_3^- (mg/l)	0.7	0.8	1	1.4	0.8	0.7	1.6	1.6	1.4	0.8	0.8	1	1.4			1.1	0.3	0.5	0.9	0.9	1.2
$N0_2^-$ (mg/l)	2.29	0.26	3.28	4.597	2.63	2.29	5.25	5.26	4.59	2.62	2.63	3.28	4.51			3.61	0.96	1.64	2.96	2.96	3.94
SO_4^{2-} (mg/l)	768	865	848	848	682	658	742	768	782	690	782	791	852			810	822	815	881	721	854

	Block C			Block C			Block F			Block F			Block G			Block G			Block G		
Parameters	S14T	S14M	S14B	SW38T	SW38M	SW38B	S17T	S17M	S17B	SW41T	SW41M	SW41B	SW11T	SW11M	SW11B	S6T	S6M	S6B	SW42T	SW42M	SW42B
PO_4^{3-} (mg/l)	0.48	0.51	0.52	0.46	0.31	0.32	0.46	0.23	0.31	0.24	0.28	0.3	0.46			0.27	0.22	0.28	0.34	0.38	0.41
NH_4^+ (mg/l)	0.32	0.36	0.47	0.42	0.36	0.31	0.74	0.75	0.66	0.36	0.37	0.47	0.66			0.51	0.18	0.25	0.44	0.45	0.56
O/G (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			<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
THC (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			<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
TPH (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			<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
PAH (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			<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
BTEX (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			<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Ni (mg/l)	0.418	0.425	0.463	0.412	0.423	0.453	0.221	0.293	0.3	0.226	0.245	0.327	0.23	0.245	0.268	0.312	0.345	0.349	0.012	0.078	0.124
Fe (mg/l)	0.117	0.128	0.134	0.053	0.072	0.125	0.081	0.113	0.137	0.049	0.068	0.096	0.049	0.076	0.092	0.096	0.102	0.126	0.113	0.12	0.136
Pb (mg/l)	<0.001	0.092	0.117	0.294	0.326	0.335	0.327	0.419	0.426	0.315	0.398	0.469	0.343	0.452	0.539	0.367	0.382	0.394	0.331	0.395	0.422
Cu (mg/l)	0.021	0.028	0.049	0.063	0.069	0.078	0.023	0.038	0.063	0.047	0.051	0.052	0.062	0.072	0.082	0.018	0.231	0.332	0.034	0.038	0.041
Cr (mg/l)	0.249	0.256	0.277	0.218	0.225	0.263	0.136	0.145	0.172	0.21	0.18	0.184	0.252	0.268	0.276	0.026	0.028	0.183	0.024	0.053	0.055
Zn (mg/l)	<0.001	0.002	0.016	0.013	0.021	0.038	0.012	0.028	0.035	<0.001	0.001	0.021	0.076	0.089	0.096	0.066	0.118	0.138	0.021	0.034	0.041
Cd (mg/l)	0.065	0.073	0.092	0.057	0.069	0.081	0.023	0.039	0.041	0.033	0.045	0.047	0.034	0.044	0.103	0.017	0.034	0.062	0.022	0.031	0.041
Mn (mg/l)	0.018	0.022	0.029	0.071	0.082	0.096	0.029	0.043	0.068	0.045	0.046	0.052	0.07	0.087	0.123	0.042	0.051	0.063	0.017	0.026	0.035
Ba (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	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Co (mg/l)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

	Block C			Block C			Block F			Block F			Block G			Block G			Block G		
Parameters	S14T	S14M	S14B	SW38T	SW38M	SW38B	S17T	S17M	S17B	SW41T	SW41M	SW41B	SW11T	SW11M	SW11B	S6T	S6M	S6B	SW42T	SW42M	SW42B
Hg (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	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
V (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	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
K (mg/l)	392	382	378	345	362	376	372	380	382	370	374	380	356	362	381	359	376	382	368	372	386
Na (mg/l)	9619	9986	10125	10056	10075	10086	10026	9986	9789	10016	10018	10023	9998	10029	10078	10124	10236	9986	10024	10028	10045
Mg (mg/l)	1250	1254	1024	1238	1246	1345	1342	1245	1325	1233	1240	1243	1206	1213	1229	1212	1204	1235	1235	1258	1266
Ca (mg/l)	406	416	426	410	413	418	401	409	406	408	413	420	406	424	458	421	423	419	412	413	416
HUF (cfu/ml)	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL			NIL	NIL	NIL	NIL	NIL	NIL
HUB (cfu/ml) x 10^2	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL			NIL	NIL	NIL	NIL	NIL	NIL
THB (cfu/ml) x 10^2	2.02	2.14	2.01	2.01	1.92	1.81	2.37	1.82	2.01	2.16	2.03	1.84	1.83			2.35	2.03	1.82	2.31	1.58	2.13
THF (cfu/ml) x 10^2	1.22	1.03	1.07	1.28	7.3	8.4	1.18	1.21	1.14	1.24	1.01	1.11	1.13			1.03	1.24	1.17	1.12	8.7	1.27
SRB (cfu/ml) x 10^3	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA			NA	NA	NA	NA	NA	NA
Coliforms	0	0	0	0	0	0	0	0	0	0	0	0	0			0	0	1	0	1	0

Appendix 2.2.3: Detailed results for Water column physicochemical and microbiological measurements in the JK Field during dry season Contd.

	Block I			Block I			Block A			Block A			Block J			Block J		
Parameters	S22T	S22M	S22B	SW46T	SW46M	SW46B	S13T	S13M	S13B	SW37T	SW37M	SW37B	S23T	S23M	S23B	SW47T	SW47M	SW47B
Temp. (^oC)	28.6	28.1	27.7	28.2	27.7	27.4	28.3	28	27.8	28.9	28.3	27.9	28.7	28.4	27.7	31.5	27.1	26.2
PH	8.55	8.55	8.54	8.52	8.54	8.53	8.53	8.52	8.53	8.52	8.53	8.53	8.57	8.56	8.56	8.52	8.55	8.56
EC (µS/cm)	40700	45200	46600	40500	42500	44900	40000	44800	46200	40.3	42200	42600	40800	43400	45200	40700	42000	47800
Turb. (NTU)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DO (mg/l)	6	4.2	3.4	5.8	4.1	3.7	5.9	4.1	3.6	5.9	4.1	3.6	6.1	4.2	3.7	6	4	3.3
TDS (mg/l)	28491	31648	32620	28350	29751	31430	28000	31360	32340	28210	29541	29820	28560	30380	31642	28492	29400	33463
Cl^- (mg/l)	14697	16322	16828	14625	15347	16214	11553	12319	13061	14522	15239	15383	14733	15672	16322	14697	15167	17261
Alkalinity (mg/l)	12	12	14	16	16	12	16	12	14	10	16	12	16	10	14	12	12	16
Colour (mg/l)	0.01	0.01	0.01	0.01	0.01	0.01	0	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.02	0.01
TSS (mg/l)	18	26	20	26	22	24	32	30	30	24	32	22	20	32	28	26	20	22
COD (mg/l)	190	163	158	181	175	179	192	185	188	167	174	192	177	183	182	168	172	182
BOD (mg/l)	0.7	0.5	0.5	0.7	0.6	0.2	0.8	0.6	0.5	0.5	0.4	0.1	0.8	0.6	0.6	0.5	0.3	0.3
NO_3^- (mg/l)	1.4	1.6	1.8	1.2	0.8	0.8	0.8	0.7	0.9	1.2	1	1.4	0.9	0.9	0.7	0.9	1.2	1.6
$N0_2^-$ (mg/l)	4.51	525	5.91	3.94	2.63	2.63	2.63	2.29	2.96	3.94	3.28	4.59	2.96	2.96	2.29	2.96	3.94	5.25
SO_4^{2-} (mg/l)	762	846	858	681	741	782	670	680	761	695	784	689	796	782	746	861	874	884
PO_4^{3-} (mg/l)	0.36	0.9	0.44	0.38	0.46	0.54	0.24	0.32	0.38	0.54	0.52	0.48	0.46	0.48	0.52	0.6	0.42	0.48

	Block I			Block I			Block A			Block A			Block J			Block J		
Parameters	S22T	S22M	S22B	SW46T	SW46M	SW46B	S13T	S13M	S13B	SW37T	SW37M	SW37B	S23T	S23M	S23B	SW47T	SW47M	SW47B
NH_4^+ (mg/l)	0.68	0.75	0.84	0.56	0.37	0.36	0.37	0.33	0.42	0.56	0.46	0.43	0.44	0.43	0.33	0.45	0.56	0.74
O/G (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	<0.001	<0.001	<0.001	<0.001	<0.001
THC (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	<0.001	<0.001	<0.001	<0.001	<0.001
TPH (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	<0.001	<0.001	<0.001	<0.001	<0.001
PAH (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	<0.001	<0.001	<0.001	<0.001	<0.001
BTEX (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	<0.001	<0.001	<0.001	<0.001	<0.001
Ni (mg/l)	0.134	0.326	0.341	0.098	0.294	0.345	0.232	0.325	0.434	0.465	0.353	0.524	0.385	0.422	0.431	0.178	0.211	0.285
Fe (mg/l)	0.071	0.093	0.121	0.057	0.098	0.115	0.072	0.116	0.129	0.063	0.097	0.112	0.062	0.087	0.114	0.083	0.092	0.112
Pb (mg/l)	0.223	0.315	0.352	0.129	0.141	0.265	0.395	0.411	0.426	<0.001	<0.001	<0.001	<0.001	0.095	0.183	0.158	0.194	0.237
Cu (mg/l)	0.053	0.074	0.096	0.051	0.071	0.079	0.018	0.066	0.079	0.054	0.069	0.078	0.07	0.093	0.159	0.014	0.032	0.042
Cr (mg/l)	0.226	0.239	0.312	0.017	0.057	0.069	0.118	0.123	0.136	0.314	0.323	0.339	0.156	0.234	0.241	0.028	0.228	0.034
Zn (mg/l)	0.032	0.048	0.063	0.005	0.041	0.048	0.064	0.082	0.119	0.145	0.181	0.195	<0.001	0.008	0.023	0.024	0.041	0.043
Cd (mg/l)	0.045	0.069	0.083	0.041	0.052	0.055	0.026	0.047	0.061	0.022	0.064	0.088	0.069	0.083	0.115	0.061	0.074	0.079
Mn (mg/l)	0.023	0.041	0.074	0.077	0.054	0.058	0.021	0.035	0.057	0.049	0.054	0.069	0.08	0.094	0.138	0.053	0.072	0.087
Ba (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	<0.01	<0.01	<0.01
Co (mg/l)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Hg (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	<0.001	<0.001	<0.001	<0.001	<0.001

	Block I			Block I			Block A			Block A			Block J			Block J		
Parameters	S22T	S22 M	S22B	SW46 T	SW46 M	SW46 B	S13T	S13 M	S13B	SW37 T	SW37 M	SW37 B	S23T	S23 M	S23B	SW47 T	SW47 M	SW47 B
V (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	<0.001	<0.001	<0.001	<0.001	<0.001
K (mg/l)	377	380	386	368	375	382	391	389	386	376	348	388	385	387	390	372	385	326
Na (mg/l)	9976	9989	10123	10350	10460	9865	9499	9564	9689	10036	10068	10065	9078	9099	9998	10245	10273	10132
Mg (mg/l)	1226	1228	1230	1268	1298	1258	1232	1245	1234	1245	1287	1290	1241	1293	1246	1243	1290	1282
Ca (mg/l)	414	418	420	406	409	416	404	407	410	416	407	409	402	410	412	418	413	417
HUF (cfu/ml)	NIL	NIL	NIL	NIL	NIL	NIL							NIL	NIL	NIL	NIL	NIL	NIL
HUB (cfu/ml) x 10^2	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL
THB (cfu/ml) x 10^2	2.1	1.82	2.01	2.11	1.75	2.24	NIL	NIL	NIL	NIL	NIL	NIL	2.23	1.83	1.68	2.16	2.02	2.34
THF (cfu/ml) x 10^2	1.36	1.24	1.19	1.25	0.87	1.72	2.07	1.72	1.81	2.26	1.88	1.72	1.21	1.01	1.17	1.03	1.41	1.13
SRB (cfu/ml) x 10^3	NA	NA	NA	NA	NA	NA	1.16	1.32	1.18	9.6	1.19	0.84	NA	NA	NA	NA	NA	NA
Coliforms	0	0	0	0	0	0	NA	NA	NA	NA	NA	NA	0	0	0	0	0	0

Appendix 2.2.3: Detailed results for Water column physicochemical and microbiological measurements in the JK Field during dry season Contd.

	Block GS			Block GS			Block K			Block K			Block HE			Block HE			Control 1			Control 2			Control 3		
Parameters	S19T	S19M	S19B	SW43T	SW43M	SW43B	S24T	S24M	S24B	SW48T	SW48M	SW48B	S21T	S21M	S21B	SW45T	SW45M	SW45B	CONTL 1 TP	CONTL 1MD	CONTL 1 BT	CONTL 2 TP	CONTL 2MD	CONTL 2 BT	CONTL 3 TP	CONTL 3MD	CONTL 3 BT
Temp. (°C)	27.9	27.5	27.2	28.3	27.9	27.7	29	28.6	28.1	28.1	26.8	24.9	28.4			28	27.9	27.4	28.6	28.1	27.6	28.3	28	27.4	29.1	28.7	28.2
PH	8.54	8.55	8.54	8.48	8.59	8.58	8.57	8.59	8.59	8.59	8.58	8.55	8.52			8.55	8.52	8.54	8.51	8.49	848	8.57	8.58	8.59	8.51	8.47	8.5
EC (µS/cm)	40700	43900	45200	40900	41900	48500	40900	44100	48300	40800	46200	47600	39700			39500	44000	46800	42100	45200	46100	41900	42100	42800	38300	39300	39700
Turb. (NTU)	0	0	0	0	0	0	0	0	0	0	0	0	0			0	0	0	0	0	0	0	0	0	0	0	0
DO (mg/l)	6	4	3.4	6	4	3.4	6	4	3.4	6.1	4.2	3.6	5.9			5.8	4	3.5	6	4.7	3.2	6	4.1	3.5	6	4.1	3.6
TDS (mg/l)	28491	30732	31640	28630	29331	33950	28630	30870	33810	28560	32341	32320	27790			27650	30800	32761	29470	31640	32270	29330	29472	29960	26813	27510	27790
Cl^- (mg/l)	13751	12678	13317	14769	15130	17514	14769	15925	17442	14733	16683	17189	14336			14264	15889	16900	15203	16322	16647	15131	14842	15456	13831	14192	14336
Alkalinity (mg/l)	16	12	12	16	12	14	16	12	14	16	14	14	16			16	12	14	12	8	14	16	12	14	8	8	14

	Block GS			Block GS			Block K			Block K			Block HE			Block HE			Control 1			Control 2			Control 3		
Parameters	S19T	S19M	S19B	SW43T	SW43M	SW43B	S24T	S24M	S24B	SW48T	SW48M	SW48B	S21T	S21M	S21B	SW45T	SW45M	SW45B	CONTL1 TP	CONTL1MD	CONTL1 BT	CONTL2 TP	CONTL2MD	CONTL2 BT	CONTL3 TP	CONTL3MD	CONTL3 BT
Colour (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	0.01	0.01	0	0.01	0.01	0.02	0.01	0.01	0.01	0.01
TSS (mg/l)	26	34	30	18	26	24	16	24	30	20	20	30	20			20	24	18	22	30	28	22	26	24	20	24	20
COD (mg/l)	173	168	175	178	163	172	175	178	172	189	182	183	175			201	206	209	199	181	187	179	172	192	186	192	188
BOD (mg/l)	0.6	0.5	0.5	0.6	0.3	0.2	1.1	0.9	0.5	0.2	0.2	0.1	0.9			0.4	0.2	0.2	0.5	0.4	0.2	0.9	0.7	0.4	0.6	0.3	0.2
NO_3^- (mg/l)	0.8	0.9	1	1	0.8	0.8	0.9	1	1.2	0.8	0.9	1	0.8			0.7	0.9	1	1.2	1.4	1.8	0.9	1.4	1.8	0.9	0.6	0.6
$N0_2^-$ (mg/l)	2.63	2.95	3.29	3.28	2.63	2.63	2.96	3.29	394	2.63	2.94	3.28	2.63			2.29	2.96	3.28	3.94	4.59	5.92	2.96	4.59	5.91	2.96	1.97	1.98
SO_4^{2-} (mg/l)	682	782	798	691	781	824	824	818	814	659	652	681	651			693	671	723	687	724	784	789	689	677	714	758	761
PO_4^{3-} (mg/l)	0.3	0.28	0.26	0.38	0.4	0.45	0.38	0.42	0.48	0.24	0.29	0.31	0.24			0.41	0.49	0.52	0.42	0.48	0.51	0.42	0.48	0.51	0.41	0.45	0.54

	Block GS			Block GS			Block K			Block K			Block HE			Block HE			Control 1			Control 2			Control 3		
Parameters	S19T	S19M	S19B	SW43T	SW43M	SW43B	S24T	S24M	S24B	SW48T	SW48M	SW48B	S21T	S21M	S21B	SW45T	SW45M	SW45B	CONTL 1 TP	CONTL 1MD	CONTL 1 BT	CONTL 2 TP	CONTL 2MD	CONTL 2 BT	CONTL 3 TP	CONTL 3MD	CONTL 3 BT
NH_4^+ (mg/l)	0.38	0.46	0.48	0.47	0.37	0.38	0.45	0.47	0.57	0.36	0.42	0.47	0.36			0.33	0.44	0.47	0.56	0.68	0.84	0.43	0.68	0.84	0.43	0.28	0.28
O/G (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			<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
THC (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			<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
TPH (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			<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
PAH (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			<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
BTEX (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			<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Ni (mg/l)	0.124	0.315	0.474	0.208	0.256	0.334	0.123	0.138	0.223	0.045	0.345	0.568	0.268	0.312	0.315	0.245	0.318	0.335	0.764	0.76	0.354	0.974	0.265	1.06	0.133	0.695	0.721
Fe (mg/l)	0.049	0.062	0.091	0.083	0.088	0.127	0.029	0.054	0.087	0.063	0.085	0.096	0.047	0.073	0.095	0.068	0.096	0.105	0.024	0.011	0.045	0.014	0.023	0.017	0.437	0.045	0.044
Pb (mg/l)	0.225	0.21	< 0.	0.325	0.447	0.459	0.352	0.395	0.428	0.116	0.164	0.236	0.03	0.151	0.187	0.356	0.394	0.443	0.094	0.105	0.107	0.289	0.664	0.695	<0.001	<0.001	<0.001

	Block GS			Block GS			Block K			Block K			Block HE			Block HE			Control 1			Control 2			Control 3		
Parameters	S19T	S19M	S19B	SW43T	SW43M	SW43B	S24T	S24M	S24B	SW48T	SW48M	SW48B	S21T	S21M	S21B	SW45T	SW45M	SW45B	CONTL 1 TP	CONTL 1MD	CONTL 1 BT	CONTL 2 TP	CONTL 2MD	CONTL 2 BT	CONTL 3 TP	CONTL 3MD	CONTL 3 BT
			001																								
Cu (mg/l)	0.026	0.058	0.048	0.013	0.037	0.041	0.136	0.138	0.142	0.018	0.027	0.034	0.068	0.072	0.085	0.032	0.042	0.048	0.025	0.054	0.041	0.022	0.034	0.051	0.029	0.038	0.047
Cr (mg/l)	0.216	0.322	0.239	0.025	0.228	0.318	0.268	0.269	0.273	0.038	0.039	0.042	0.194	0.218	0.265	0.041	0.043	0.047	0.166	0.082	0.152	0.172	0.038	0.036	<0.001	0.002	0.004
Zn (mg/l)	< 0.001	0.002	0.04	0.001	0.006	0.018	0.011	0.023	0.026	0.03	0.041	0.048	0.043	0.068	0.083	0.027	0.038	0.039	0.01	0.032	0.075	0.038	0.071	0.075	0.008	0.022	0.081
Cd (mg/l)	0.017	0.025	0.053	0.024	0.049	0.054	0.024	0.026	0.034	0.048	0.051	0.055	0.071	0.095	0.113	0.026	0.028	0.031	0.018	<0.001	<0.001	0.009	<0.001	<0.001	<0.001	0.012	0.059
Mn (mg/l)	0.021	0.032	< 0.001	0.06	0.079	0.081	0.034	0.036	0.041	0.046	0.048	0.057	< 0.001	0.005	0.011	0.062	0.071	0.076	0.122	<0.001	0.014	0.051	0.157	0.126	0.075	0.108	0.023
Ba (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	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Co (mg/l)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Hg (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	< 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	<0.001
V (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	< 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	<0.001

	Block GS			Block GS			Block K			Block K			Block HE			Block HE			Control 1			Control 2			Control 3		
Parameters	S19T	S19M	S19B	SW43T	SW43M	SW43B	S24T	S24M	S24B	SW48T	SW48M	SW48B	S21T	S21M	S21B	SW45T	SW45M	SW45B	CONTL 1 TP	CONTL 1MD	CONTL 1 BT	CONTL 2 TP	CONTL 2MD	CONTL 2 BT	CONTL 3 TP	CONTL 3MD	CONTL 3 BT
K (mg/l)	377	390	369	372	388	390	375	372	362	327	323	326	369	370	376	365	372	376	376.6	370.8	373.4	379.9	380.9	383.9	390.4	383.3	375.6
Na (mg/l)	9869	9048	9076	10325	10333	10338	10123	10032	10045	10142	9865	9989	9423	9986	10034	10124	10245	10256	9948	9959	9968	9863	9783	9968	9563	9789	10231
Mg (mg/l)	1235	1249	1274	1250	1249	1246	1212	1213	1124	1231	1232	1223	1211	1251	1260	1242	1243	1248	1124	1205	1160	1243	1269	1288	1145	1177	1255
Ca (mg/l)	402	408	412	403	407	410	403	407	403	420	426	430	408	410	412	412	413	414	400	401	403	406	408	410	408	409	411
HUF (cfu/ml)	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL
HUB (cfu/ml) x 10^2	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL
THB (cfu/ml) x 10^2	2.03	2.12	1.86	2.35	2.09	1.82	2.23	1.73	2.06	1.83	2.37	1.89	2.03	1.91	1.23	2.32	1.81	1.62	2.13	2.27	2.01	2.37	1.86	2.17	2.19	2.08	1.78
THF (cfu/m	1.12	1.03	1.22	1.19	1.23	9.8	1.19	1.31	1.08	1.01	1.16	1.09	1.31	1.01	1.02	1.17	8.7	9.3	1.11	1.15	1.22	1.02	1.12	1.1	1.03	1.19	1.18

	Block GS			Block GS			Block K			Block K			Block HE			Block HE			Control 1			Control 2			Control 3		
Parameters	S 19 T	S 19 M	S 19 B	S W 43 T	S W 43 M	S W 43 B	S 24 T	S 24 M	S 24 B	S W 48 T	S W 48 M	S W 48 B	S 21 T	S 21 M	S 21 B	S W 45 T	S W 45 M	S W 45 B	CO NTL 1 TP	CO NTL 1M D	CO NTL 1 BT	CO NTL 2 TP	CO NTL 2M D	CO NTL 2 BT	CO NTL 3 TP	CO NTL 3M D	CO NTL 3 BT
l) x 10^2																											
SRB (cfu/ml) x 10^3	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Coliforms	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0

Appendix 2.2.4: Detailed results for Water column physicochemical and microbiological measurements in the JK Field during wet season

	Block D			Block E			Block E			Block H			Block H		
Parameters	S15T	S15M	S15B	S16T	S16M	S16B	SW40 T	SW40 M	SW40 B	S20T	S20M	S20B	SW44 T	SW44 M	SW44 B
Temp. (°C)	27.7	27.2	26.8	28.1	27.2	26.4	27.7	26.8	25.8	26.9	26.2	26.2	27.8	27.2	26.5
PH	8.41	8.32	8.29	8.3	8.12	8.07	8.39	8.43	8.12	8.42	8.49	8.54	8.49	8.49	8.5
EC (µS/cm)	37600	39000	42100	34100	35500	38800	41700	43400	45100	39200	40000	43300	31800	34400	37490
Turb. (NTU)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DO (mg/l)	5.9	4.5	4	6	4.4	3.7	5.9	4.3	3.8	5.9	4.5	3.7	6.1	4.2	3.7
TDS (mg/l)	26320	27300	29470	23870	24850	27160	29190	30380	31570	27440	28000	30310	22260	24080	26243
Cl^- (mg/l)	15052	15591	17551	13460	14282	15506	16670	17360	18034	15705	16017	17324	12808	14947	14984
Alkalinity (mg/l)	16	12	8	16	12	8	12	8	8	16	12	8	16	8	8
Colour (mg/l)	0.01	0.01	0	0.01	0.01	0.01	0.01	0	0.01	0.01	0.01	0.01	0.01	0.01	0.01

	Block D			Block E			Block E			Block H			Block H		
Parameters	S15T	S15M	S15B	S16T	S16M	S16B	SW40 T	SW40 M	SW40 B	S20T	S20M	S20B	SW44 T	SW44 M	SW44 B
TSS (mg/l)	20	24	30	24	34	40	22	32	36	20	28	36	22	26	38
COD (mg/l)	164	178	176	182	184	180	172	166	170	188	182	184	180	194	194
BOD (mg/l)	0.6	0.3	1	0.6	1.3	0.8	0.6	2	1.7	1.1	0.5	0.7	0.8	0.5	0.5
NO_3^- (mg/l)	0.8	1.2	1.3	0.9	0.9	1.2	0.7	1.2	1.7	0.5	1.2	1.3	0.8	1.1	1.1
$N0_2^-$ (mg/l)	0.59	0.88	0.96	0.66	0.66	0.88	1.25	0.51	0.88	0.37	0.88	0.96	0.59	0.81	0.81
SO_4^{2-} (mg/l)	1410	1620	1740	1350	1740	1920	1800	1470	1470	1500	1680	1800	1620	1710	1740
PO_4^{3-} (mg/l)	0.9	1.21	1.32	0.32	0.86	0.94	1.01	0.71	0.89	0.96	1.32	1.2	1.13	1.26	1.2
NH_4^+ (mg/l)	0.37	0.55	0.6	0.41	0.41	0.55	0.79	0.32	0.55	0.23	0.55	0.6	0.37	0.51	0.51
O/G (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	<0.001	<0.001
THC (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	<0.001	<0.001
TPH (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	<0.001	<0.001
PAH (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	<0.001	<0.001
BTEX (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	<0.001	<0.001
Ni (mg/l)	0.148	0.185	0.223	0.107	0.139	0.169	0.139	0.183	0.241	0.153	0.169	0.223	0.129	0.174	0.179
Fe (mg/l)	0.114	0.127	0.138	0.079	0.153	0.178	0.097	0.109	0.129	0.192	0.141	0.193	0.039	0.064	0.106
Pb (mg/l)	0.217	0.322	0.328	<0.001	<0.001	0.009	0.224	0.259	0.327	0.284	0.297	0.318	0.219	0.222	0.267
Cu (mg/l)	0.011	0.019	0.032	<0.001	0.006	0.063	0.039	0.047	0.059	0.052	0.064	0.082	0.035	0.043	0.049
Cr (mg/l)	0.104	0.119	0.163	0.117	0.132	0.159	0.142	0.263	0.271	0.182	0.234	0.287	0.122	0.138	0.138
Zn (mg/l)	0.043	0.049	0.062	0.023	0.037	0.048	0.015	0.022	0.029	0.015	0.023	0.065	0.027	0.028	0.032
Cd (mg/l)	0.022	0.028	0.031	<0.001	0.022	0.032	0.043	0.049	0.052	0.021	0.029	0.042	0.042	0.069	0.069
Mn (mg/l)	0.034	0.043	0.052	0.063	0.071	0.078	0.031	0.039	0.052	0.036	0.048	0.065	0.025	0.028	0.037
Ba (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
Co (mg/l)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Hg (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	<0.001	<0.001
V (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	<0.001	<0.001
K (mg/l)	348	372	382	356	363	384	361	347	353	349	359	381	382	391	397

	Block D			Block E			Block E			Block H			Block H		
Parameters	S15T	S15M	S15B	S16T	S16M	S16B	SW40 T	SW40 M	SW40 B	S20T	S20M	S20B	SW44 T	SW44 M	SW44 B
Na (mg/l)	9782	9985	10128	10162	10281	10295	10047	10049	10065	10119	10128	10254	10015	10027	10062
Mg (mg/l)	1127	1153	1210	1192	1221	1259	1247	1252	1227	1210	1245	1269	1219	1236	1249
Ca (mg/l)	429	427	454	411	442	449	411	421	437	418	432	461	409	421	425
HUF (cfu/ml)	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL
HUB (cfu/ml) x 10^2	NIL	NIL	NIL	NIL	NIL	0.03X1 02	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL
THB (cfu/ml) x 10^2	2.17X1 02	1.53X1 02	1.74X1 02	1.92X1 02	1.67X1 02	1.82X1 02	2.66X1 02	1.32X1 02	1.44X1 02	1.55X1 02	1.39X1 02	1.74X1 02	2.31X1 02	2.03X1 02	1.43X1 02
THF (cfu/ml) x 10^2	1.10X1 02	0.67X1 01	0.80X1 01	0.88X1 01	0.71X1 01	0.57X1 01	1.17X1 02	0.98X1 01	0.89X1 01	0.63X1 01	0.50X1 01	0.84X1 01	1.17X1 02	1.21X1 02	1.38X1 02
SRB (cfu/ml) x 10^3	1.22 x103	1.43 x103	1.33 x103	1.20 x103	1.58 x103	1.73 x103	1.38 x103	1.32 x103	1.42 x103	1.17 x103	1.24 x103	1.28 x103	1.33 x103	1.53 x103	1.72 x103
Coliforms	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 2.2.4: Detailed results for Water column physicochemical and microbiological measurements in the JK Field during wet season Contd.

	Block C			Block C			Block F			Block F			Block G		
Parameters	S14T	S14M	S14B	SW38T	SW38 M	SW38B	S17T	S17M	S17B	SW41T	SW41 M	SW41B	SW42T	SW42 M	SW42B
Temp. (°C)	28.2	27.4	26.7	27	26.9	26.3	27.6	27.3	25.6	27.4	27.7	26.9	26.8	26.8	26.4
PH	8.43	8.4	8.38	8.44	8.41	8.39	8.33	8.39	8.42	8.39	8.44	8.45	8.33	8.29	8.26
EC (µS/cm)	38500	42900	44400	41200	42500	43900	35200	38600	45300	35900	37100	42100	30100	34400	38390
Turb. (NTU)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DO (mg/l)	5.9	4.4	3.9	6	4.4	3.9	5.9	4.5	3.7	5.8	4.3	3.9	5.9	4.4	4
TDS (mg/l)	26950	30030	31080	28840	29750	30730	24640	27020	31710	25130	25970	29470	21070	24080	26873

	Block C			Block C			Block F			Block F			Block G		
Parameters	S14T	S14M	S14B	SW38T	SW38M	SW38B	S17T	S17M	S17B	SW41T	SW41M	SW41B	SW42T	SW42M	SW42B
Cl^- (mg/l)	15392	17153	17750	16500	17011	17551	14084	15449	18119	14370	14853	16841	12070	14966	15364
Alkalinity (mg/l)	16	8	8	12	8	8	16	12	12	16	12	8	12	12	8
Colour (mg/l)	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0	0	0.01	0.01	0	0.01
TSS (mg/l)	22	30	36	24	32	36	22	36	42	22	26	36	20	26	32
COD (mg/l)	176	170	174	182	174	158	172	168	170	170	186	188	200	186	180
BOD (mg/l)	0.5	1.2	0.9	1.9	1.5	1.4	0.4	0.9	0.6	0.9	1.3	1.7	0.7	0.5	1.1
NO_3^- (mg/l)	1.3	1.2	0.8	1.3	1.5	1.9	1.3	0.5	0.4	0.9	1.2	1.3	1.1	1	1.3
$N0_2^-$ (mg/l)	0.96	0.88	0.59	1.11	1.25	1.25	0.96	0.37	0.29	0.66	0.88	0.96	0.81	0.74	0.96
SO_4^{2-} (mg/l)	1470	1560	1770	1770	1650	1770	1770	1800	1950	1740	1590	1650	1500	1620	1740
PO_4^{3-} (mg/l)	0.92	1.32	1.05	0.94	0.86	0.86	0.18	0.42	0.42	0.99	0.85	0.87	1.01	1.26	1.17
NH_4^+ (mg/l)	0.6	0.55	0.37	0.69	0.79	0.88	0.6	0.23	0.18	0.41	0.59	0.6	0.51	0.46	0.6
O/G (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	<0.001	<0.001
THC (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	<0.001	<0.001
TPH (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	<0.001	<0.001
PAH (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	<0.001	<0.001
BTEX (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	<0.001	<0.001
Ni (mg/l)	0.248	0.311	0.373	0.219	0.237	0.289	0.171	0.204	0.262	0.169	0.193	0.284	0.063	0.069	0.116

	Block C			Block C			Block F			Block F			Block G		
Parameters	S14T	S14M	S14B	SW38T	SW38M	SW38B	S17T	S17M	S17B	SW41T	SW41M	SW41B	SW42T	SW42M	SW42B
Fe (mg/l)	0.121	0.139	0.139	0.092	0.105	0.117	0.094	0.131	0.157	0.052	0.059	0.081	0.098	0.116	0.121
Pb (mg/l)	<0.001	0.058	0.092	0.212	0.265	0.309	0.311	354	0.382	0.259	0.315	0.319	0.311	0.325	0.381
Cu (mg/l)	0.011	0.015	0.024	0.042	0.071	0.083	0.011	0.015	0.039	0.026	0.042	0.049	0.062	0.066	0.092
Cr (mg/l)	0.039	0.188	0.193	0.113	0.169	0.215	0.103	0.129	0.141	0.056	0.126	0.139	0.019	0.037	0.049
Zn (mg/l)	0.01	0.015	0.032	0.022	0.028	0.035	0.051	0.046	0.068	0.013	0.017	0.026	0.029	0.033	0.036
Cd (mg/l)	<0.001	0.005	0.008	0.028	0.049	0.055	0.018	0.025	0.039	0.031	0.039	0.048	0.029	0.047	0.059
Mn (mg/l)	0.043	0.065	0.087	0.044	0.049	0.057	0.034	0.061	0.073	0.026	0.037	0.049	0.021	0.028	0.031
Ba (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
Co (mg/l)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Hg (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	<0.001	<0.001
V (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	<0.001	<0.001
K (mg/l)	382	369	381	336	362	382	369	373	391	329	363	369	353	382	389
Na (mg/l)	9827	10224	10325	9987	10018	10027	10151	10254	10321	9967	10012	10034	10018	10037	10052
Mg (mg/l)	1261	1198	1224	1228	1237	1240	1206	1253	1315	1212	1226	1250	1221	1232	1247
Ca (mg/l)	418	424	456	412	424	429	414	422	439	404	409	415	411	417	425
HUF (cfu/ml)	NIL	NIL	NIL	NIL	NIL	0.05X102	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL
HUB (cfu/ml) x 10^2	NIL	NIL	0.06X102	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	0.01X102	NIL	0.04X102

	Block C			Block C			Block F			Block F			Block G		
Parameters	S14T	S14M	S14B	SW38T	SW38 M	SW38B	S17T	S17M	S17B	SW41T	SW41 M	SW41B	SW42T	SW42 M	SW42B
THB (cfu/ml) x 10^2	1.48X10 2	1.29X10 2	1.18X1 02	1.70X1 02	1.55X1 02	1.21X1 02	2.01X1 02	2.18X1 02	2.33X1 02	2.71X1 02	2.16X1 02	1.53X1 02	1.89X1 02	2.02X1 02	1.15X1 02
THF (cfu/ml) x 10^2	0.52X10 1	0.60X10 1	0.82X1 01	0.72X1 01	1.01X1 02	0.90X1 01	1.28X1 02	1.15X1 02	1.20X1 02	1.13X1 02	1.04X1 02	0.59X1 01	1.02X1 02	1.06X1 02	0.92X1 01
SRB (cfu/ml) x 10^3	1.37 X 103	1.33 X 103	1.41 x103	1.83 x103	2.02 x103	1.75 x103	1.35x1 03	1.81 x103	1.57 x103	1.37 x103	1.28 x103	1.35 x103	1.37 x103	1.52 x103	1.74 x103
Coliforms	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 2.2.4: Detailed results for Water column physicochemical and microbiological measurements in the JK Field during wet season Contd.

	Block I			Block I			Block A			Block A			Block J			Block J		
Parameters	S22T	S22M	S22B	SW46 T	SW46 M	SW46 B	S13T	S13M	S13B	SW37 T	SW37 M	SW37 B	S23T	S23M	S23B	SW47 T	SW47 M	SW47 B
Temp. (°C)	26.5	25.5	24.9	28	27.8	27.5	27.7	27.2	26.8	27.1	26.9	26.9	27.2	26.7	26.2	27.6	26.8	26
PH	8.41	8.4	8.48	8.39	8.31	8.23	8.41	8.32	8.29	8.37	8.41	8.33	8.41	8.56	8.65	8.57	8.61	8.59
EC (µS/cm)	37300	38800	41600	37300	41800	43800	37600	39000	42100	39600	41700	43800	34800	36400	39100	35800	38600	43400
Turb. (NTU)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DO (mg/l)	6	4.3	3.7	5.9	4	3.7	5.9	4.5	4	5.9	4.6	3.9	6.1	4.6	3.9	6	4.4	3.9
TDS (mg/l)	26110	27160	29120	26110	29260	30660	26320	27300	29470	27720	29190	29490	24360	25480	27370	25060	27020	30380
Cl^- (mg/l)	14910	15506	16642	14938	16727	17522	15052	15591	17551	15847	16670	17522	13972	14654	15705	14370	15563	17409

	Block I			Block I			Block A			Block A			Block J			Block J		
Parameters	S22T	S22M	S22B	SW46T	SW46M	SW46B	S13T	S13M	S13B	SW37T	SW37M	SW37B	S23T	S23M	S23B	SW47T	SW47M	SW47B
Alkalinity (mg/l)	12	12	8	12	12	8	16	12	8	12	12	8	12	12	8	16	12	8
Colour (mg/l)	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
TSS (mg/l)	20	26	38	20	24	30	20	24	30	24	30	34	22	24	36	20	28	36
COD (mg/l)	188	170	164	178	184	180	164	178	176	168	176	188	172	184	180	170	174	180
BOD (mg/l)	0.4	1	0.9	1.1	0.5	1.4	0.6	0.3	1	1.5	1.3	0.9	0.9	1.4	1.4	0.8	1.2	0.9
NO_3^- (mg/l)	0.6	1	1.3	0.6	0.9	1	0.8	1.2	1.3	1.6	1.8	1.8	0.4	0.7	0.9	0.8	1	0.6
$N0_2^-$ (mg/l)	0.44	0.74	0.96	0.44	0.66	0.74	0.59	0.88	0.96	1.18	1.01	1.18	0.29	0.51	0.66	0.59	0.74	0.44
SO_4^{2-} (mg/l)	1770	1680	1920	1560	1620	180	1410	1620	1740	1710	1650	1710	1410	1590	1710	1380	1560	1800
PO_4^{3-} (mg/l)	0.24	0.21	0.84	1.13	1.12	1.13	0.9	1.21	1.32	0.73	0.78	0.78	0.76	0.81	0.81	0.37	0.39	0.86
NH_4^+ (mg/l)	0.27	0.46	0.6	0.27	0.41	0.46	0.37	0.55	0.6	0.74	0.64	0.64	0.18	0.32	0.41	0.37	0.46	0.27
O/G (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	<0.001	<0.001	<0.001	<0.001	<0.001
THC (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	<0.001	<0.001	<0.001	<0.001	<0.001
TPH (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	<0.001	<0.001	<0.001	<0.001	<0.001
PAH (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	<0.001	<0.001	<0.001	<0.001	<0.001
BTEX (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	<0.001	<0.001	<0.001	<0.001	<0.001
Ni (mg/l)	0.119	0.231	0.286	0.115	0.186	0.211	0.225	0.281	0.326	0.243	0.262	0.268	0.253	0.276	0.284	0.109	0.173	0.196

	Block I			Block I			Block A			Block A			Block J			Block J		
Parameters	S22T	S22M	S22B	SW46T	SW46M	SW46B	S13T	S13M	S13B	SW37T	SW37M	SW37B	S23T	S23M	S23B	SW47T	SW47M	SW47B
Fe (mg/l)	0.065	0.103	0.198	0.043	0.067	0.118	0.057	0.132	0.168	0.045	0.066	0.105	0.073	0.088	0.097	0.057	0.086	0.104
Pb (mg/l)	0.238	0.275	0.291	0.229	0.235	0.248	0.256	0.282	0.285	<0.001	<0.001	<0.001	0.005	0.019	0.095	0.123	0.161	0.229
Cu (mg/l)	0.033	0.039	0.057	0.058	0.063	0.065	0.015	0.032	0.052	0.038	0.056	0.056	0.081	0.089	0.114	0.045	0.051	0.059
Cr (mg/l)	0.197	0.229	0.273	0.025	0.041	0.048	0.098	0.123	0.129	0.154	0.259	0.316	0.12	0.162	0.218	0.065	0.122	0.132
Zn (mg/l)	0.024	0.039	0.058	0.011	0.025	0.029	0.027	0.054	0.127	0.097	0.142	0.173	0.056	0.061	0.069	0.022	0.027	0.035
Cd (mg/l)	0.013	0.032	0.039	0.028	0.042	0.049	0.031	0.033	0.033	0.021	0.035	0.041	0.022	0.029	0.052	0.044	0.059	0.073
Mn (mg/l)	0.02	0.032	0.056	0.031	0.057	0.062	0.038	0.051	0.063	0.032	0.037	0.041	0.071	0.079	0.079	0.027	0.036	0.044
Ba (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	<0.01	<0.01	<0.01
Co (mg/l)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Hg (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	<0.001	<0.001	<0.001	<0.001	<0.001
V (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	<0.001	<0.001	<0.001	<0.001	<0.001
K (mg/l)	349	365	392	339	342	391	331	362	364	363	377	381	367	367	384	396	396	331
Na (mg/l)	9955	9971	10121	10095	10098	10102	9722	9821	9953	10024	10031	10052	9440	9753	9984	10096	10105	10135
Mg (mg/l)	1232	1241	1258	1236	1242	1261	1262	1237	1217	1218	1229	1236	1237	1298	1298	1213	1242	1247
Ca (mg/l)	429	441	457	412	418	422	415	429	433	409	413	402	409	429	437	408	419	419
HUF (cfu/ml)	NIL	NIL	NIL	NIL	NIL	0.01X102	NIL	NIL	0.03X102	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	0.01X102

	Block I			Block I			Block A			Block A			Block J			Block J		
Parameters	S22T	S22M	S22B	SW46 T	SW46 M	SW46 B	S13T	S13M	S13B	SW37 T	SW37 M	SW37 B	S23T	S23M	S23B	SW47 T	SW47 M	SW47 B
HUB (cfu/ml) x 10^2	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	0.08X 102	NIL	NIL	NIL	0.02X 102	NIL	NIL	NIL	NIL
THB (cfu/ml) x 10^2	1.93X 102	1.66X 102	1.38X 102	2.10X 102	2.13X 102	1.11X 102	2.50X 102	2.34X 102	2.10X 102	1.58X 102	2.14X 102	2.23X 102	1.90X 102	1.68X 102	1.82X 102	2.13X 102	2.48X 102	2.02X 102
THF (cfu/ml) x 10^2	0.70X 101	0.57X 101	0.60X 101	1.22X 102	1.40X 102	0.64X 101	1.31X 102	1.12X 102	1.24X 102	1.05X 102	1.07X 102	1.26X 102	0.88X 101	0.63X 101	0.72X 101	1.32X 102	1.14X 102	1.02X 102
SRB (cfu/ml) x 10^3	1.12 x103	1.20 x103	1.33 x103	1.73 x103	1.53 x103	1.81 x103	1.41 X 103	1.35 X 103	1.52 X 103	1.34 x103	1.77 x103	1.38 x103	1.42 x103	1.31 x103	1.33 x103	1.35 x103	1.42 x103	1.08 x103
Coliforms	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 2.2.4: Detailed results for Water column physicochemical and microbiological measurements in the JK Field during wet season Contd.

	Block GS			Block GS			Block K			Block K			Block HE			Block HE			Control1			Control2			Control3		
Parameters	S19T	S19M	S19B	SW43T	SW43M	SW43B	S24T	S24M	S24B	SW48T	SW48M	SW48B	S21T	S21M	S21B	SW45T	SW45M	SW45B	CONTL 1 TP	CONTL 1MD	CONTL 1 BT	CONTL 2 TP	CONTL 2MD	CONTL 2 BT	CONTL 3 TP	CONTL 3MD	CONTL 3 BT
Temp. (°C)	28.9	28.7	27.1	27.6	27.2	26.9	26.4	27.1	27.2	27.6	26.9	26.3	28.9	27.4	26.8	28.1	27.6	26.4	27.5	27.3	26.9	28.1	27.6	26.8	28.1	27.8	27.5
PH	8.56	8.43	8.56	8.35	8.54	8.69	8.14	8.21	8.3	8.44	8.43	8.49	8.35	8.51	8.59	8.21	8.3	8.4	8.24	8.21	8.36	8.52	8.52	8.48	8.51	8.31	8.23
EC (µS/cm)	31900	34300	37400	33200	35300	36900	31100	34400	37490	33200	35700	38250	34100	38370	43200	27150	34600	43400	40400	42000	45000	38700	40300	41500	38300	41800	43800
Turb. (NTU)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.3	0	0
DO (mg/l)	5.9	4.5	4	5.9	4.3	4	5.9	4.3	3.9	5.8	4.3	3.9	5.8	4.4	3.7	5.8	4.4	3.9	6	4.4	3.8	5.9	4.5	3.7	5.9	3.8	3.4
TDS (mg/l)	22330	24010	26180	23240	24710	25830	21770	24080	26243	23240	24990	26775	23870	26859	30024	13580	17300	30380	28070	29400	31500	27090	28210	29050	36810	29260	30660
Cl^- (mg/l)	12780	13745	14998	13291	14171	14824	12467	14995	13802	13291	14256	15336	13688	15449	17295	11019	13944	17466	16046	16812	18005	15478	16131	16614	15307	16751	17563

	Block GS			Block GS			Block K			Block K			Block HE			Block HE			Control1			Control2			Control3		
Parameters	S19T	S19M	S19B	SW43T	SW43M	SW43B	S24T	S24M	S24B	SW48T	SW48M	SW48B	S21T	S21M	S21B	SW45T	SW45M	SW45B	CONTL1 TP	CONTL 1MD	CONTL1 BT	CONTL2 TP	CONTL 2MD	CONTL2 BT	CONTL3 TP	CONTL 3MD	CONTL3 BT
Alkalinity (mg/l)	16	12	8	12	8	8	16	12	4	12	8	8	16	12	8	16	12	8	16	12	4	16	12	8	8	12	12
Colour (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	0.01	0.01	0	0.01	0.01	0	0.01	0	0.01	0.01	0.01	0.01	0.01
TSS (mg/l)	22	36	42	18	24	34	18	24	32	22	26	34	22	26	34	20	26	34	22	28	36	22	28	38	20	32	22
COD (mg/l)	174	168	178	174	170	168	176	174	174	186	182	184	170	186	184	194	182	190	201	186	188	182	176	190	188	195	200
BOD (mg/l)	0.5	0.7	0.9	0.6	0.5	1.2	1.3	0.1	0.6	0.4	1	0.7	1.1	0.7	0.4	1.5	1	0.9	0.8	1.1	1.2	1.3	1.2	1.2	1	1.1	1.3
NO_3^-	0.8	1.1	1.4	0.7	1.4	0.7	0.7	1.2	1.2	0.8	1	1	0.7	0.9	1.3	0.8	1.2	1.3	0.9	1.1	0.8	0.6	0.8	0.8	0.9	0.7	0.6

	Block GS			Block GS			Block K			Block K			Block HE			Block HE			Control1			Control2			Control3		
Parameters	S19T	S19M	S19B	SW43T	SW43M	SW43B	S24T	S24M	S24B	SW48T	SW48M	SW48B	S21T	S21M	S21B	SW45T	SW45M	SW45B	CONTL 1TP	CONTL 1MD	CONTL 1BT	CONTL 2TP	CONTL 2MD	CONTL 2BT	CONTL 3TP	CONTL 3MD	CONTL 3BT
(mg/l)																											
N0$_2^-$ (mg/l)	0.59	0.81	1.03	0.51	1.03	0.51	0.51	0.88	0.88	0.59	0.74	0.74	0.51	0.66	0.96	0.59	0.88	0.96	0.48	0.52	0.76	0.59	0.74	0.74	0.51	0.82	0.84
SO_4^{2-} (mg/l)	1500	1620	1740	840	1350	1650	1470	1470	1590	1440	1590	1740	1470	1590	1740	1500	1590	1650	1442	1560	1800	1500	1650	1650	1380	1440	16500
PO_4^{3-} (mg/l)	0.76	0.93	0.82	0.93	1.13	1.82	0.71	0.89	0.93	0.89	1.1	1.23	1.1	1	0.91	0.86	0.93	0.89	1.2	1.82	1.82	0.85	0.97	1.05	0.83	0.99	1.2
NH_4^+ (mg/l)	0.37	0.51	0.65	0.32	0.65	0.32	0.32	0.55	0.55	0.37	0.46	0.46	0.32	0.41	0.6	0.37	0.55	0.6	0.37	0.42	0.51	0.28	0.37	0.37	0.28	0.33	0.44
O/G (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	<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	<0.001
THC (m	<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	<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	<0.001

	Block GS			Block GS			Block K			Block K			Block HE			Block HE			Control1			Control2			Control3		
Parameters	S19T	S19M	S19B	SW43T	SW43M	SW43B	S24T	S24M	S24B	SW48T	SW48M	SW48B	S21T	S21M	S21B	SW45T	SW45M	SW45B	CONTL1 TP	CONTL1MD	CONTL1 BT	CONTL2 TP	CONTL2MD	CONTL2 BT	CONTL3 TP	CONTL3MD	CONTL3 BT
g/l)																											
TPH (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	<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	<0.001
PAH (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	<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	<0.001
BTEX (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	<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	<0.001
Ni (mg/l)	0.181	0.198	0.198	0.134	0.159	0.187	0.169	0.213	0.218	0.116	0.149	0.243	0.187	0.214	0.236	0.028	0.257	0.261	0.258	0.297	0.311	0.173	0.192	0.199	0.125	0.201	0.255
Fe (mg/l)	0.084	0.164	0.182	0.092	0.115	0.119	0.025	0.062	0.079	0.047	0.114	0.127	0.204	0.075	0.082	0.369	0.104	0.112	0.137	0.137	0.139	0.127	0.131	0.133	0.122	0.124	0.137
Pb (mg/l)	0.182	0.215	0.221	0.295	0.329	0.385	0.027	0.122	0.159	0.114	0.131	0.195	0.309	0.342	0.37	<0.001	0.095	0.112	0.102	0.118	0.124	0.138	0.302	0.522	<0.001	<0.001	<0.001
Cu (m	0.023	0.039	0.045	0.023	0.036	0.041	0.67	0.115	0.131	0.03	0.041	0.048	0.026	0.049	0.051	0.057	0.059	0.074	0.029	0.034	0.045	0.039	0.046	0.052	0.022	0.038	0.051

	Block GS			Block GS			Block K			Block K			Block HE			Block HE			Control1			Control2			Control3		
Parameters	S19T	S19M	S19B	SW43T	SW43M	SW43B	S24T	S24M	S24B	SW48T	SW48M	SW48B	S21T	S21M	S21B	SW45T	SW45M	SW45B	CONTL 1 TP	CONTL 1MD	CONTL 1 BT	CONTL 2 TP	CONTL 2MD	CONTL 2 BT	CONTL 3 TP	CONTL 3MD	CONTL 3 BT
g/l)																											
Cr (mg/l)	0.224	0.251	0.289	<0.001	0.035	0.046	0.206	0.234	0.255	0.016	0.034	0.049	0.096	0.131	0.185	0.315	0.332	0.362	0.105	0.111	0.119	0.136	0.138	0.152	<0.001	0.013	0.019
Zn (mg/l)	0.013	0.016	0.037	0.013	0.004	0.015	0.037	0.052	0.064	0.021	0.036	0.039	0.038	0.056	0.072	<0.001	0.019	0.026	0.016	0.027	0.043	0.018	0.034	0.052	0.016	0.019	0.025
Cd (mg/l)	0.022	0.036	0.065	0.063	0.068	0.087	0.022	0.026	0.034	0.028	0.031	0.101	0.107	0.109	0.115	0.025	0.037	0.039	0.005	<0.001	<0.001	0.011	<0.001	<0.001	0.011	0.015	0.023
Mn (mg/l)	0.054	0.062	0.081	0.035	0.042	0.049	0.012	0.029	0.037	0.027	0.031	0.039	0.005	0.014	0.021	0.042	0.048	0.053	0.035	0.038	0.042	0.047	0.083	0.089	0.035	0.073	0.077
Ba (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	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Co (mg/l)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Hg (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	<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	<0.001

	Block GS			Block GS			Block K			Block K			Block HE			Block HE			Control1			Control2			Control3		
Parameters	S19T	S19M	S19B	SW43T	SW43M	SW43B	S24T	S24M	S24B	SW48T	SW48M	SW48B	S21T	S21M	S21B	SW45T	SW45M	SW45B	CONTL 1 TP	CONTL 1MD	CONTL 1 BT	CONTL 2 TP	CONTL 2MD	CONTL 2 BT	CONTL 3 TP	CONTL 3MD	CONTL 3 BT
V (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	<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	<0.001
K (mg/l)	368	385	393	359	371	385	356	382	397	349	349	353	375	384	384	355	359	374	364	381	385	353	372	377	372	379	395
Na (mg/l)	9718	9815	9932	10215	10224	10239	10211	10254	10268	10056	10078	10110	9915	9962	10028	10119	10154	10186	9963	10021	10064	9962	9971	10062	9892	9931	10052
Mg (mg/l)	1229	1241	1263	1242	1271	1273	1253	1295	1296	1213	1226	1243	1223	1224	1279	1219	1227	1234	1194	1194	1210	1224	1231	1257	1184	1191	1214
Ca (mg/l)	434	442	455	412	412	419	415	428	435	416	422	434	415	424	437	417	424	447	406	417	426	405	412	418	401	415	428
HUF (cfu/ml)	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	0.01X102	NIL	NIL	NIL	0.02X102	NIL	NIL	NIL	NIL	0.02X102	NIL	NIL	NIL	NIL	NIL
HUB (cfu/	NIL	0.05X102	NIL	NIL	0.02X102	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	0.07X102	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL

	Block GS			Block GS			Block K			Block K			Block HE			Block HE			Control1			Control2			Control3		
Parameters	S19T	S19M	S19B	SW43T	SW43M	SW43B	S24T	S24M	S24B	SW48T	SW48M	SW48B	S21T	S21M	S21B	SW45T	SW45M	SW45B	CONTL 1TP	CONTL 1MD	CONTL 1BT	CONTL 2TP	CONTL 2MD	CONTL 2BT	CONTL 3TP	CONTL 3MD	CONTL 3BT
ml) x 10^2																											
THB (cfu/ml) x 10^2	1.89X102	2.10X102	1.72X102	1.78X102	2.57X102	1.18X102	1.51X102	1.76X102	1.72X102	2.62X102	1.98X102	2.19X102	2.42X102	1.86X102	1.65X102	1.95X102	2.16X102	2.01X102	1.63X102	1.41X102	1.20X102	1.65X102	2.13X102	2.36X102	2.11X102	2.01X102	1.83X102
THF (cfu/ml) x 10^2	0.89X101	1.20X102	1.14X102	1.33X102	1.01X102	0.92X101	0.85X101	0.84X101	0.69X101	1.16X102	0.88X101	1.12X102	1.31X102	0.98X101	0.74X101	1.02X102	1.17X102	1.22X102	0.71X101	0.58X101	0.54X101	0.70X101	1.09X102	1.17X102	1.10X102	1.66X102	1.11X102
SRB (cfu/ml) x 10^3	1.30x103	1.70x103	1.02x103	1.33x103	1.40x103	1.32x103	1.53x103	1.38x103	1.22x103	1.34x103	1.58x103	1.33x103	1.13x103	1.35x103	1.04x103	1.48x103	1.51x103	1.91x103	1.47x103	1.55x103	1.31x103	1.50X103	1.33x103	1.37x103	1.33x103	1.28x103	1.40x103
Coliforms	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 2.3: Detailed results for Sediment physicochemical and microbiological measurements in the JK Field

Appendix 2.3.1: Detailed results for Sediment physicochemical and microbiological measurements in the JK Field during dry season

	BLOCK D								BLOCK E							
	200m		500m		800m		1200m		200m		500m		800m		1200m	
Parameters	ASW5	ASW6	SW5	SW6	S3	SW27	S15T	SW39	ASW7	ASW8	SW7	SW8	S4	SW28	S16T	SW40T
pH	7.5	7.59	7.78	7.53	7.28	7.69	7.49	7.43	7.06	7.64	7.39	7.54	7.53	7.26	7.47	7.34
Redox (mV)	-35.6	-43.4	-52.5	-35.1	-22.4	-50.7	-32.8	-36.8	-17.5	-42.3	-29.8	-35.6	-51.4	-21.7	-33.7	-23.9
Temp (^oC)	15.1	15.5	16.3	18.7	17.9	17.2	16.2	18.5	16.5	17.7	18.2	18.6	16.8	17.6	16.9	17.7
colour	GREY	GREY	GREY	GREY	GREY	GREY	GREY	GREY	GREY	GREY	GREY	GREY	GREY	GREY	GREY	GREY
Cl^- (mg/kg)	10508	9281	9172	9227	9606	9172	9678	9281	9353	10111	8946	8631	8883	9534	9894	9208
TOC (%)	1.97	1.76	2.49	2.14	0.19	2.15	0.59	1	2.91	2.93	2.75	1.68	0.31	1.89	0.46	1.71
NO3- (mg/kg)	0.7	0.1	0.8	0.7	0.8	0.5	0.4	0.6	0.3	0.7	1.1	0.8	0.5	0.3	1.2	0.2
PO_4^{3-} (mg/kg)	0.21	0.27	0.24	0.19	0.45	0.24	0.21	0.14	0.19	0.79	0.21	0.18	0.22	0.21	0.51	0.12
NH_4^+ (mg/kg)	0.32	0.05	0.37	0.33	0.37	0.37	0.2	0.29	0.14	0.32	0.51	0.37	0.23	0.14	0.54	0.09
Sand (%)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Silt (%)	54.55	52.94	47.47	51.28	55.41	47.54	54.18	49.74	52.5	51.2	48.83	48.78	53.08	51.02	53.64	49.29
Clay (%)	45.45	47.06	52.2	48.72	44.56	52.43	45.72	50.19	47.5	48.59	50.96	51.2	46.84	48.93	46.24	50.56
THC (mg/kg)	6.9	5.7	11.3	13.3	6.3	6.3	6.7	12.7	12.7	6	6.3	5.7	6	<0.001	12	6.7
TPH (mg/kg)	<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	<0.001	<0.001	<0.001
PAH (mg/kg)	<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	<0.001	<0.001	<0.001
BTEX (mg/kg)	<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	<0.001	<0.001	<0.001
Ni (mg/kg)	19.898	25.45	16.245	128	116.213	17.084	60.951	27.009	142.188	50.151	135	120	78.235	80.857	42.356	56.89

	BLOCK D								BLOCK E							
	200m		500m		800m		1200m		200m		500m		800m		1200m	
Parameters	ASW5	ASW6	SW5	SW6	S3	SW27	S15T	SW39	ASW7	ASW8	SW7	SW8	S4	SW28	S16T	SW40T
Fe (mg/kg)	6985	6897	6423	6421	6699	5774	6556	6764	6777	7036	5897	7125	7893	5527	7893	7112
Pb (mg/kg)	2.448	3.102	2.669	3.64	<0.001	5.342	4.602	3.697	2.198	2.682	3.845	4.251	3.968	<0.001	2.863	3.584
Cu (mg/kg)	11.619	11.852	6.234	8.04	14.177	9.869	10.436	9.154	6.858	12.683	5.032	5.289	12.182	12.643	8.112	8.235
Cr (mg/kg)	37.333	35.216	31.28	32.404	26.518	6.183	29.963	18.233	34.516	32.259	30.124	21.312	38.247	30.321	32.543	20.351
Zn (mg/kg)	36.822	23.964	32.178	36.595	56.908	46.427	40.155	47.471	34.268	30.851	28.145	23.234	61.098	28.47	25.281	30.124
Cd (mg/kg)	10.107	9.332	4.235	5.532	7.681	2.16	6.65	9.866	7.696	3.918	4.389	3.128	5.335	10.619	5.392	6.012
Ba (mg/kg)	10	12	11	13	11	15	11	16	9	14	9	8	9	9	13	11
Co (mg/kg)	12.036	15.214	14.217	15.324	11.036	15.214	14.213	15.231	12.347	10.217	12.326	13.694	10.254	13.695	16.125	16.315
Ag (mg/kg)	<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	<0.001	<0.001	<0.001
V (mg/kg)	<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	<0.001	<0.001	<0.001
K (mg/kg)	594	513	564	594	594	614	704	716	641	598	545	563	536	572	658	548
Na (mg/kg)	1215	11345	11456	11646	11485	11814	11922	12057	11606	11028	11456	11312	11356	11079	11245	11205
Mg (mg/kg)	2818	2456	2312	2467	2755	2893	2424	2790	2966	2923	2123	2135	2560	2928	2345	2245
Ca (mg/kg)	1009	1045	1124	1208	1230	1192	1222	1210	1034	1037	1235	1345	1135	1201	1325	1145
HUF (cfu/g)	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL
HUB (cfu/g)	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	0.20X101	NIL	NIL	NIL	NIL	NIL
THB (cfu/g)	2.14X102	1.92X102	1.94X102	2.18X102	2.11X102	2.21X102	2.34X102	2.09X102	2.01X102	2.21X102	2.10X102	2.13X102	2.09X102	2.31X102	2.26X102	2.11X101

	BLOCK D								BLOCK E							
	200m		500m		800m		1200m		200m		500m		800m		1200m	
Parameters	ASW5	ASW6	SW5	SW6	S3	SW27	S15T	SW39	ASW7	ASW8	SW7	SW8	S4	SW28	S16T	SW40T
THF (cfu/g)	9.10X101	1.12X101	7.10X101	6.60X101	6.20X101	8.70X101	1.03X101	1.02X102	7.20X101	1.16X101	7.00X101	9.10X101	7.10X101	1.12X102	6.30X101	8.30X101
SRB (cfu/g)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Appendix 2.3.1: Detailed results for Sediment physicochemical and microbiological measurements in the JK Field during dry season Contd.

	BLOCK H								BLOCK C (mini cluster)							
	200m		500m		800m		1200m		200m		500m		800m		1200m	
Parameters	ASW15	ASW16	SW15	SW16	S8	SW32	S20T	SW44T	ASW3	ASW4	SW3	SW4	S2	SW26	S14T	SW38T
pH	7.46	7.42	7.43	7.5	7.64	7.48	7.62	7.5	7.47	7.35	7.25	7.45	7.23	7.21	7.4	7.45
Redox (mV)	-29.2	-29.4	-30.9	-34.9	-57.3	-34.2	-41.9	-35.9	-33.7	-25.7	-21.3	-32.5	19.7	-18.7	-29.9	-32.5
Temp (^{o}C)	17.1	16.2	15.4	16.8	15.7	18.4	15.4	17.2	16.8	16.2	16.8	17.8	17.4	16.5	16.7	17.4
colour	GREY	GREY	GREY	GREY	GREY	GREY	GREY	GREY	GREY	GREY	GREY	GREY	GREY	GREY	GREY	GREY
Cl^- (mg/kg)	9461	8261	9457	8919	9569	8992	8919	9208	9461	9024	9100	9100	9.281	9208	9858	9358
TOC (%)	1.65	1.44	2.47	2.49	0.59	0.7	1.97	1.2	3.05	2.09	1.61	1.94	1.44	2.77	0.29	0.97
NO3- (mg/kg)	0.7	0.4	0.8	0.5	0.6	0.9	0.6	0.5	1.1	0.5	0.2	1.2	1.4	1.1	0.5	0.4
PO_4^{3-} (mg/kg)	0.24	0.48	0.29	0.42	0.18	0.26	0.55	0.5	0.4	0.56	0.2	0.88	0.71	0.29	0.27	0.1
NH_4^+ (mg/kg)	0.32	0.21	0.37	0.26	0.28	0.42	0.29	0.23	0.51	0.23	0.09	0.55	0.65	0.51	0.24	0.19
Sand (%)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Silt (%)	53.19	51.47	47.92	44.44	51.85	57.36	55.43	47.83	52.83	52.94	46.04	48.93	51.27	47.27	51.26	51.35

	BLOC K H								BLOCK C (mini cluster)							
	200m		500m		800m		1200m		200m		500m		800m		1200m	
Clay (%)	46.54	48.44	52.2	55.51	48.01	42.66	44.35	52.15	47.17	47.06	53.71	50.97	48.57	52.7	48.69	48.63
THC (mg/kg)	5.7	<0.001	11	6	5.7	12	6.7	6.3	12.7	6	12	6	12	12	12.7	12
TPH (mg/kg)	<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	<0.001	<0.001	<0.001
PAH (mg/kg)	<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	<0.001	<0.001	<0.001
BTEX (mg/kg)	<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	<0.001	<0.001	<0.001
Ni (mg/kg)	7.941	25.456	21.842	26.128	42.123	129	24.125	66.002	93.295	82.12	23.25	14.415	2.877	18.012	98.797	74.23
Fe (mg/kg)	6647	7851	5099	5207	6682	7483	7124	6876	7239	7124	6534	6323	6832	5591	6537	6589
Pb (mg/kg)	<0.001	3.215	3.171	<0.001	5.177	4.539	4.218	3.957	2.345	2.112	3.262	4.286	4.166	3.657	3.478	4.82
Cu (mg/kg)	7.06	5.964	9.347	9.42	13.822	10.105	6.542	13.375	11.3	12.218	6.235	14.037	11.032	4.639	4.506	11.248
Cr (mg/kg)	21.983	29.347	30.993	27.089	34.86	36.796	22.234	35.346	83.576	45.381	4.238	21.556	37.851	7.62	103.513	19.238
Zn (mg/kg)	25.925	36.247	30.189	15.617	27.01	28.565	16.754	37.269	28.451	25.369	26.234	41.274	21.637	47.491	8.704	21.234
Cd (mg/kg)	<0.001	7.358	5.914	8.556	8.36	0.238	8.275	0.925	5.481	8.647	8.753	5.656	3.328	0.69	2.435	4.237
Ba (mg/kg)	9	8	13	12	13	16	11	10	13	7	12	7	14	11	6	11
Co (mg/kg)	10.23	15.63	15.263	14.254	15.214	14.289	16.034	18.954	11.264	13.254	12.369	15.698	10.258	12.348	15.223	16.321
Ag (mg/kg)	<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	<0.001	<0.001	<0.001
V (mg/kg)	<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	<0.001	<0.001	<0.001
K (mg/kg)	548	516	602	581	606	665	645	674	610	543	653	649	578	579	757	658

	BLOCK H								BLOCK C (mini cluster)							
	200m		500m		800m		1200m		200m		500m		800m		1200m	
Na (mg/kg)	11655	11345	11706	11977	11930	11489	11325	12334	11739	11345	11231	11998	11295	11524	11851	11245
Mg (mg/kg)	2681	2342	2596	2654	2189	2074	2312	2767	2789	2653	2245	2494	2665	2825	2959	2412
Ca (mg/kg)	1216	1218	1205	1195	1216	1202	1120	1236	1089	1034	1125	1208	1231	1182	1215	1325
HUF (cfu/g)	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL
HUB (cfu/g)	NIL	NIL	NIL	NIL	NIL	0.10X101	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL
THB (cfu/g)	2.32X102	1.97X102	1.86X102	2.15X102	2.01X102	2.01X102	2.21X102	2.24X102	2.31X102	2.09X102	1.83X102	2.16X102	2.30X102	2.32X102	2.11X102	1.94X102
THF (cfu/g)	9.30X101	8.10X101	8.20X101	8.70X101	6.20X101	9.30X101	9.40X101	8.40X101	8.10X101	9.20X101	8.20X101	5.40X101	7.30X101	8.00X101	7.80X101	7.10X101
SRB (cfu/g)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Appendix 2.3.1: Detailed results for Sediment physicochemical and microbiological measurements in the JK Field during dry season Contd.

	BLOCK F								BLOCK G							
	200m		500m		800m		1200m		200m		500m		800m		1200m	
Parameters	ASW9	ASW10	SW9	SW10T	S5	SW29	S17T	SW41T	ASW11	ASW12T	SW11T	SW12	S6T	SW30	S18	SW42T
pH	7.72	7.79	7.74	7.81	7.5	7.38	7.42	7.38	7.48	7.61	7.48	7.71	7.56	7.54	7.49	7.3
Redox (mV)	-52.9	-59.6	-54.7	-62.3	-34.6	-27.8	-30.8	-28.1	-33.8	-41.7	-34.8	-49.8	-38.4	-36.8	-33.8	-28.9
Temp (^{o}C)	17.4	17	18	17.2	16.7	17.1	16.3	18.4	16.5	16.8	16.2	16.8	16	16.8	16.2	16.7
colour	GREY	GREY	GREY	GREY	GREY	GREY	GREY	GREY	GREY	GREY	GREY	GREY	GREY	GREY	GREY	GREY
Cl^- (mg/kg)	8883	9784	8742	8883	8558	9461	9858	9100	9492	9136	9202	8844	9497	9208	8992	9136
TOC (%)	3.81	2.79	1.46	2.24	0.26	1.26	1.39	1.53	1.43	1.12	1.92	1.27	0.54	1.04	1.84	1.07

	BLOC K F								BLOC K G							
	200m		500m		800m		1200m		200m		500m		800m		1200m	
Parameters	ASW9	ASW10	SW9	SW10T	S5	SW29	S17T	SW41T	ASW11	ASW12T	SW11T	SW12	S6T	SW30	S18	SW42T
NO3- (mg/kg)	0.3	0.9	0.4	0.8	1.1	0.5	1.3	0.3	0.3	0.7	0.5	0.7	1.3	0.2	0.3	0.8
PO_4^{3-} (mg/kg)	0.36	0.18	0.24	0.14	0.89	0.51	0.78	0.18	0.27	0.44	0.38	0.47	0.24	0.16	0.59	0.29
NH_4^+ (mg/kg)	0.42	0.42	0.19	0.37	0.51	0.23	0.61	0.14	0.14	0.32	0.22	0.33	0.61	0.13	0.64	0.37
Sand (%)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Silt (%)	51.37	51.33	47.83	49.04	54.2	52.08	54.99	52.7	53.53	52.72	47.81	43.1	53.03	53.7	54.1	51.16
Clay (%)	47.95	48.47	52.17	50.73	45.45	47.9	44.81	47.11	46.23	47.17	53.87	56.8	46.93	46.24	45.78	48.81
THC (mg/kg)	20	12	6	12	12.7	6.7	6.3	11.3	6.7	12.7	6.3	11.3	6.7	<0.001	6	6.3
TPH (mg/kg)	0.08	<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	<0.001	<0.001
PAH (mg/kg)	<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	<0.001	<0.001	<0.001
BTEX (mg/kg)	<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	<0.001	<0.001	<0.001
Ni (mg/kg)	46.123	68.292	132	60.252	68.235	103.171	35.621	65.32	56.132	103.799	50.231	42.356	322.108	74.235	28.12	45.231
Fe (mg/kg)	7564	7139	5889	6987	7456	4194	6987	6897	6897	7246	6852	7125	6727	5689	7125	5689
Pb (mg/kg)	1.953	2.356	4.152	3.294	2.968	4.999	3.669	4.227	2.161	<0.001	3.622	4.271	<0.001	3.928	5.141	4.328
Cu (mg/kg)	8.653	9.156	13.636	9.234	7.349	6.356	7.231	6.238	10.342	11.641	12.158	10.234	9.898	7.235	9.328	7.231
Cr (mg/kg)	39.521	34.743	22.12	15.031	32.812	0.209	28.238	24.123	38.435	47.768	14.235	13.289	39.528	10.234	27.147	28.395
Zn (mg/kg)	35.272	43.606	33.005	20.148	52.281	44.656	20.452	24.212	39.523	40.957	22.234	17.235	26.087	32.012	18.473	21.328

	BLOCK F								BLOCK G							
	200m		500m		800m		1200m		200m		500m		800m		1200m	
Parameters	ASW9	ASW10	SW9	SW10T	S5	SW29	S17T	SW41T	ASW11	ASW12T	SW11T	SW12	S6T	SW30	S18	SW42T
Cd (mg/kg)	5.964	5.597	<0.001	1.258	9.281	8.401	3.452	5.126	8.102	<0.001	2.28	5.124	11.87	13.258	6.451	10.234
Ba (mg/kg)	8	11	11	13	14	6	16	13	11	14	15	13	16	8	12	10
Co (mg/kg)	13.471	10.268	17.265	14.959	11.471	15.247	13.163	14.265	15.23	11.216	12.365	12.354	10.236	14.026	16.124	15.214
Ag (mg/kg)	<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	<0.001	<0.001	<0.001
V (mg/kg)	<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	<0.001	<0.001	<0.001
K (mg/kg)	543	584	543	546	524	692	568	612	513	600	653	542	576	653	612	548
Na (mg/kg)	11125	11279	11219	11312	11456	11152	11421	11325	11456	11479	11125	11325	11672	11235	11325	11421
Mg (mg/kg)	2789	2432	2551	2123	2345	2006	2215	2345	2123	2458	2245	2214	2679	1986	2145	2245
Ca (mg/kg)	1014	1048	1200	1245	1120	1211	1245	1224	1012	1151	1325	1245	1228	1256	1325	1325
HUF (cfu/g)	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL
HUB (cfu/g)	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL
THB (cfu/g)	2.35X102	1.86X102	1.83X102	2.12X102	1.87X102	2.28X102	2.32X102	2.06X102	2.02X102	1.98X102	2.32X102	2.18X102	2.16X102	2.11X102	2.37X102	2.31X102
THF (cfu/g)	1.09X101	8.20X101	8.20X101	8.20X101	5.90X101	9.30X102	1.21X102	8.00X101	9.10X101	8.20X101	9.30X101	6.60X101	8.30X101	8.10X101	8.10X102	7.20X101
SRB (cfu/g)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Appendix 2.3.1: Detailed results for Sediment physicochemical and microbiological measurements in the JK Field during dry season Contd.

	BLOC K I								BLOC K A							
	200m		500m		800m		1200m		200m		500m		800m		1200m	
Parameters	ASW19	ASW20	SW19T	SW20	S10	SW34	S22T	SW46T	ASW1	ASW2	SW1	SW2	S1	SW25	S13T	SW37T
pH	7.27	7.44	7.53	7.34	7.47	7.31	7.32	7.39	7.12	7.72	7.46	7.43	6.98	7.78	7.58	7.49
Redox (mV)	-11.9	-31.6	-35.8	-25.8	-32.2	-24.8	-24.8	-29.7	-6.9	-54.6	-30.3	-28.9	-7.8	-55.8	-39.5	-46.3
Temp (°C)	16.5	16.9	16.5	16.2	17	16	16.5	16.5	15.8	16.5	17.1	16.4	16.8	17.2	16	16.4
colour	GREY	GREY	GREY	GREY	GREY	GREY	GREY	GREY	GREY	GREY	GREY	GREY	GREY	GREY	GREY	GREY
Cl^- (mg/kg)	10003	8486	8775	9208	9281	8956	9432	9461	9994	9172	9227	9457	10833	8992	9281	9387
TOC (%)	1.35	1.43	1.44	2	1.09	0.95	1.61	1.07	2.41	2.12	2.73	1.03	1.65	1.97	0.96	1.09
NO3- (mg/kg)	0.5	0.7	0.7	0.5	0.8	0.3	1.2	0.2	1.3	0.9	0.7	0.4	1.2	1.5	0.4	0.8
PO_4^{3-} (mg/kg)	0.56	0.64	0.6	0.57	0.29	0.19	0.88	0.25	0.14	0.18	0.21	0.24	0.89	0.2	0.18	0.14
NH_4^+ (mg/kg)	0.23	0.35	0.33	0.23	0.32	0.14	0.55	0.12	0.6	0.42	0.33	0.19	0.56	0.63	0.2	0.37
Sand (%)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Silt (%)	53.41	51.24	49.55	48.9	52.79	56.1	54.46	48.78	52.83	54.05	48.38	47.37	54.52	46.81	45.45	51.96
Clay (%)	46.45	48.68	50.4	51.23	47.13	43.86	45.38	51.19	47.17	45.95	51.41	52.63	45.43	53.19	54.5	47.92
THC (mg/kg)	5.7	13.3	6	12.7	12.7	11.3	6.3	6.3	<0.001	6	6.3	6.7	5.7	12.7	12	6.3
TPH (mg/kg)	<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	<0.001	<0.001	<0.001
PAH (mg/kg)	<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	<0.001	<0.001	<0.001
BTEX (mg/kg)	<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	<0.001	<0.001	<0.001

	BLOCK I								BLOCK A							
	200m		500m		800m		1200m		200m		500m		800m		1200m	
Parameters	ASW19	ASW20	SW19T	SW20	S10	SW34	S22T	SW46T	ASW1	ASW2	SW1	SW2	S1	SW25	S13T	SW37T
Ni (mg/kg)	53.842	42.321	35.623	28.456	52.124	77.361	82.256	45.789	19.336	32.252	112	26.885	3.931	36.235	36.895	45.36
Fe (mg/kg)	7107	6897	6897	7123	6568	7397	7546	6589	7849	6897	6605	6533	6812	6789	6235	4563
Pb (mg/kg)	<0.001	0.955	3.725	4.183	3.865	5.135	4.106	5.113	2.869	1.963	<0.001	<0.001	3.98	3.736	3.642	3.531
Cu (mg/kg)	5.763	6.215	4.128	6.238	10.352	8.166	6.287	6.238	9.619	11.558	7.627	7.172	15.66	7.124	10.234	12.234
Cr (mg/kg)	<0.001	31.541	16.234	14.234	39.241	68.615	24.248	20.124	58.912	49.652	24.659	5.068	70.633	4.286	12.145	22.124
Zn (mg/kg)	5.1	29.472	12.018	22.123	29.543	43.993	18.354	23.124	38.282	33.957	27.815	25.103	24.786	14.234	18.124	20.145
Cd (mg/kg)	1.287	5.332	3.265	6.125	5.332	4.559	9.458	6.234	6.543	5.864	4.715	<0.001	5.403	2.18	4.235	6.234
Ba (mg/kg)	9	13	11	9	6	11	12	9	10	9	11	9	12	6	8	9
Co (mg/kg)	15.215	12.478	13.258	14.265	14.05	17.023	18.124	13.258	10.124	10.521	15.147	16.258	11.025	16.321	17.265	13.547
Ag (mg/kg)	<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	<0.001	<0.001	<0.001
V (mg/kg)	<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	<0.001	<0.001	<0.001
K (mg/kg)	692	542	546	568	564	640	623	542	577	578	717	741	719	542	611	586
Na (mg/kg)	11062	11412	11235	11125	11564	11725	11205	11452	11147	11450	11562	11073	11095	11235	11860	12560
Mg (mg/kg)	2574	2234	2456	2315	2315	2885	2132	2124	2982	2865	2754	2567	2651	2314	2145	2345
Ca (mg/kg)	1217	1240	1234	1245	1203	1217	1125	1245	1068	1078	1221	1212	1216	1452	1325	1135
HUF (cfu/g)	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL

	BLOCK I								BLOCK A							
	200m		500m		800m		1200m		200m		500m		800m		1200m	
Parameters	ASW19	ASW20	SW19T	SW20	S10	SW34	S22T	SW46T	ASW1	ASW2	SW1	SW2	S1	SW25	S13T	SW37T
HUB (cfu/g)	NIL	NIL	NIL	0.40X101	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL
THB (cfu/g)	2.02X102	2.18X102	2.49X102	2.28X102	2.19X102	2.21X102	2.13X102	2.32X102	2.01X102	2.22X102	1.96X102	2.13X102	2.17X102	2.33X102	1.94X102	2.32X102
THF (cfu/g)	1.12X101	9.70X101	8.50X101	1.02X101	7.70X101	9.60X101	1.11X102	6.80X101	1.51X101	9.20X101	6.20X101	9.10X101	8.10X101	8.30X101	7.10X101	6.80X101
SRB (cfu/g)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Appendix 2.3.1: Detailed results for Sediment physicochemical and microbiological measurements in the JK Field during dry season Contd.

	BLOCK J								BLOCK GS							
	200m		500m		800m		1200m		200m		500m		800m		1200m	
Parameters	ASW21	ASW22	SW21	SW22	S11	SW35	S23T	SW47T	ASW13	ASW14	SW13	SW14	S7	SW31	S19T	SW43T
pH	7.47	7.56	7.55	7.56	7.48	7.52	7.57	7.54	7.61	7.79	7.27	7.4	7.44	7.35	7.63	7.45
Redox (mV)	-33.5	-38.5	-38.3	-38.7	-35.5	-37.5	-38.8	-36.7	-41.6	-56.4	-21.8	-29.9	-31.9	-26.2	-48.1	-31.8
Temp (°C)	16	16.3	16.4	16.9	16.8	16.2	17.2	17	16.5	16.2	17.2	16.7	16.2	16.2	16.9	16.9
colour	GREY	GREY	GREY	GREY	GREY	GREY	GREY	GREY	GREY	GREY	GREY	GREY	GREY	GREY	GREY	GREY
Cl^- (mg/kg)	8197	8267	8992	9281	8261	9497	9100	9786	8811	8631	9606	9858	8811	9100	9172	9172
TOC (%)	1.97	2.09	0.69	1.06	1.17	1.14	1.96	1.13	1.51	1.24	0.28	0.29	0.46	0.84	1.17	1.16
NO3- (mg/kg)	0.4	0.6	0.2	0.8	1.3	0.7	0.5	0.8	0.3	0.5	0.6	0.5	0.7	0.5	0.9	0.4
PO_4^{3-} (mg/kg)	0.74	0.15	0.76	0.14	0.25	0.14	0.56	0.34	0.21	0.28	0.48	0.27	0.47	0.19	0.44	0.22
NH_4^+ (mg/kg)	0.21	0.28	0.09	0.37	0.61	0.33	0.26	0.37	0.18	0.23	0.28	0.24	0.32	0.23	0.42	0.21

	BLOCK J								BLOCK GS							
	200m		500m		800m		1200m		200m		500m		800m		1200m	
Parameters	ASW21	ASW22	SW21	SW22	S11	SW35	S23T	SW47T	ASW13	ASW14	SW13	SW14	S7	SW31	S19T	SW43T
Sand (%)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Silt (%)	51.85	52.58	48.94	47.83	53.31	51.09	54.99	47.84	48.29	51.35	51.77	51.26	52.17	51.92	54.03	52.78
Clay (%)	48.04	47.32	51.02	52.12	46.64	48.78	44.8	52.08	51.51	48.63	48.2	48.69	47.83	48.04	45.72	47.17
THC (mg/kg)	17	6.3	6.7	6.3	6.7	6.7	12.7	12	12	6.7	18	12.7	12.7	6	12	12
TPH (mg/kg)	0.03	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.05	<0.001	<0.001	<0.001	<0.001	<0.001
PAH (mg/kg)	<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	<0.001	<0.001	<0.001
BTEX (mg/kg)	<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	<0.001	<0.001	<0.001
Ni (mg/kg)	38.369	42.128	28.456	36.78	45.902	125	56.63	41.235	78.456	68.953	90.578	98.797	32.273	65.123	20.856	21.53
Fe (mg/kg)	7125	6953	6987	7012	6562	7026	7589	5687	7234	6897	6643	6537	7125	6897	6897	6789
Pb (mg/kg)	2.036	4.008	3.952	4.012	5.137	<0.001	3.667	3.967	1.584	2.336	4.007	3.478	2.665	4.251	4.331	4.215
Cu (mg/kg)	10.279	5.382	5.128	7.235	11.156	16.133	5.124	5.356	8.643	10.279	2.602	4.506	8.246	7.238	5.451	6.389
Cr (mg/kg)	35.826	41.217	12.423	10.234	58.267	64.355	18.234	18.237	52.314	33.824	92.379	103.513	28.438	11.246	24.125	26.348
Zn (mg/kg)	35.228	38.116	21.324	20.128	46.181	39.587	15.234	20.147	43.101	29.573	33.821	8.704	50.117	25.236	19.145	26.235
Cd (mg/kg)	6.134	5.327	5.324	7.238	2.99	5.084	10.245	8.127	3.924	6.628	4.593	2.435	10.569	10.234	5.473	9.234
Ba (mg/kg)	8	8	12	13	8	14	9	11	8	6	13	6	11	11	15	9
Co (mg/kg)	15.247	13.269	16.321	14.785	13.518	13.078	17.902	15.477	10.402	12.44	13.715	15.223	13.056	15.03	14.111	14.096

	BLOCK J								BLOCK GS							
	200m		500m		800m		1200m		200m		500m		800m		1200m	
Parameters	ASW21	ASW22	SW21	SW22	S11	SW35	S23T	SW47T	ASW13	ASW14	SW13	SW14	S7	SW31	S19T	SW43T
Ag (mg/kg)	<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	<0.001	<0.001	<0.001
V (mg/kg)	<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	<0.001	<0.001	<0.001
K (mg/kg)	523	542	562	532	703	664	584	543	523	518	749	757	645	589	564	646
Na (mg/kg)	11328	11123	11223	11325	11653	11982	11325	11215	11342	11120	11664	11851	11876	11325	11120	12388
Mg (mg/kg)	2228	2214	2145	2114	2523	2935	2145	2451	2312	2340	2378	2959	2456	2013	2451	2821
Ca (mg/kg)	1105	1112	1452	1246	1224	1220	1320	1236	1109	1103	1214	1215	1345	1253	1284	1238
HUF (cfu/g)	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL
HUB (cfu/g)	NIL	NIL	0.20X101	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	0.30X101	NIL	NIL
THB (cfu/g)	1.96X102	1.32X102	2.19X102	2.21X102	2.31X102	2.13X102	2.17X102	2.10X102	1.79X102	2.07X102	2.32X10	2.11X102	1.66X102	2.42X102	2.12X102	2.33X102
THF (cfu/g)	8.10X101	7.70X101	9.30X101	7.80X101	8.90X101	5.10X101	8.60X101	9.20X10	9.10X101	1.11X101	9.90X101	7.80X101	4.70X101	1.21X101	8.20X101	8.30X101
SRB (cfu/g)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Appendix 2.3.1: Detailed results for Sediment physicochemical and microbiological measurements in the JK Field during dry season Contd.

	BLOCK K								BLOCK HE										
	200m		500m		800m		1200 m		200m		500m		800m		1200 m				
Parameters	ASW 23	ASW 24	SW2 3	SW2 4	S12	SW3 6	S24T	SW4 8T	ASW1 7	ASW 18	SW1 7	SW1 8T	S9	SW3 3	S21T	SW4 5T	CONT RL 1	CONT RL 2	CONT RL 3
pH	7.42	7.63	7.57	7.65	7.56	7.42	7.61	7.42	7.57	7.87	7.86	7.4	7.89	7.53	7.54	7.34	7.35	7.4	7.32
Redox (mV)	-31.7	-43.1	-38.8	-44.2	-39.5	-30.9	-40.6	-31.1	-38.8	-69.3	-68.2	-33.4	-69.8	-37.2	-37.8	-22.9	-26.2	-28.8	-18.5
Temp (^oC)	16.9	17.2	16.7	16.1	16.5	16.7	16.5	16.7	17.4	16.7	18.2	17.5	16.4	16.7	16.8	17.6	21.5	20.1	20.8
colour	GREY	GREY	GREY	GREY	GREY	GREY	GREY	GREY	GREY	GREY	GREY	GREY	GREY	GREY	GREY	GREY	GREY	GREY	GREY
Cl^- (mg/kg)	9190	8522	9461	9208	9533	9281	8883	9852	8197	8999	9281	8631	8558	9172	9281	9353	8956	9786	9208
TOC (%)	1.21	0.88	1.34	1.74	0.33	1.26	2.11	0.78	1.21	3.12	1.64	2.54	0.64	1.19	0.88	0.77	1.52	1.69	0.9
NO3- (mg/kg)	0.2	0.8	0.1	0.9	0.7	0.4	0.5	1	1.3	0.8	1	0.4	0.8	0.8	1.4	0.7	0.7	0.5	0.9
PO_4^{3-} (mg/kg)	0.75	0.42	0.16	0.18	0.67	0.2	0.45	0.29	0.4	0.49	0.21	0.24	0.4	0.15	0.69	0.14	0.16	0.18	0.29
NH_4^+ (mg/kg)	0.32	0.38	0.05	0.42	0.33	0.19	0.22	0.46	0.61	0.37	0.46	0.21	0.37	0.37	0.64	0.33	0.33	0.23	0.42
Sand (%)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Silt (%)	52.91	51.26	43.55	47.83	53.82	51.17	53.36	45.13	51.27	51.25	48.1	46.34	53.8	53.13	52.49	45.83	70.32	15.79	27.37
Clay (%)	47.03	48.69	56.41	52.13	46.13	48.75	46.4	54.76	48.57	48.71	51.93	53.62	46.12	46.95	47.24	54.12	29.63	84.2	72.6

	BLOCK K								BLOCK HE										
	200m		500m		800m		1200m		200m		500m		800m		1200m				
Parameters	ASW23	ASW24	SW23	SW24	S12	SW36	S24T	SW48T	ASW17	ASW18	SW17	SW18T	S9	SW33	S21T	SW45T	CONTRL 1	CONTRL 2	CONTRL 3
THC (mg/kg)	18	12.7	6.7	6	12.7	12	18	<0.001	6	12	11.3	6.7	12	6.3	<0.00	12	6.7	17	6.3
TPH (mg/kg)	0.04	<0.001	<0.001	<0.001	<0.001	<0.001	0.04	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.02	<0.001
PAH (mg/kg)	<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	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
BTEX (mg/kg)	<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	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Ni (mg/kg)	52.36	39.456	40.28	23.123	46.789	63.89	72.34	29.458	150.968	85.123	52.362	21.578	80.665	58.235	35.128	43.561	24.931	29.655	20.055
Fe (mg/kg)	7012	6857	6897	6789	6986	5689	6897	5678	6647	7125	6987	5943	6772	6958	7235	5789	6728	7167	7342
Pb (mg/kg)	2.963	2.347	3.963	4.218	3.693	4.607	4.168	3.852	2.376	3.216	0.996	<0.001	5.803	3.692	3.995	4.824	24.148	20.732	25.406
Cu (mg/kg)	9.127	7.395	6.234	6.123	8.255	10.24	7.124	6.328	8.198	6.225	6.231	5.774	13.329	9.234	3.241	10.235	0.403	1.848	1.337
Cr (mg/kg)	30.278	28.683	9.123	5.123	42.316	24.373	15.234	17.659	22.849	25.362	26.123	21.13	64.96	29.234	17.245	26.235	<0.001	<0.001	<0.001
Zn (mg/kg)	35.241	37.225	16.897	18.124	28.149	23.045	20.248	19.238	42.124	37.852	19.234	18.275	36.667	27.234	14.234	30.125	8.974	24.511	15.167

	BLOCK K								BLOCK HE										
	200m		500m		800m		1200m		200m		500m		800m		1200m				
Parameters	ASW23	ASW24	SW23	SW24	S12	SW36	S24T	SW48T	ASW17	ASW18	SW17	SW18T	S9	SW33	S21T	SW45T	CONTRL 1	CONTRL 2	CONTRL 3
Cd (mg/kg)	5.337	4.953	4.235	6.128	5.327	4.789	8.234	10.235	9.734	7.256	9.123	<0.001	1.117	11.234	8.452	3.245	2.191	<0.001	<0.001
Ba (mg/kg)	11	15	11	9	10	5	14	10	12	10	14	9	9	13	9	12	13	11	17
Co (mg/kg)	11.478	18.521	18.029	15.214	13.036	15.486	12.568	15.684	13.401	12.23	17.263	18.452	16.106	15.024	13.524	16.998	19.456	20.123	16.123
Ag (mg/kg)	<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	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
V (mg/kg)	<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	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
K (mg/kg)	548	524	546	543	645	589	523	562	636	578	623	695	658	525	586	586	640.7	626.6	680.2
Na (mg/kg)	11058	11850	11256	11456	11234	11458	11452	11235	11926	11345	11345	11385	11959	11356	11123	11325	10379	10345	10856
Mg (mg/kg)	2236	2214	2104	2135	2145	2456	2130	2145	2550	2312	2145	2826	2568	2245	2145	2345	2653.9	2668.4	2751.2
Ca (mg/kg)	1114	1135	1325	1125	1245	1124	1345	1526	1217	1234	1245	1188	1232	1125	1286	1325	609	614	621
HUF (cfu/g)	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL

	BLOCK K								BLOCK HE										
	200m		500m		800m		1200m		200m		500m		800m		1200m				
Parameters	ASW23	ASW24	SW23	SW24	S12	SW36	S24T	SW48T	ASW17	ASW18	SW17	SW18T	S9	SW33	S21T	SW45T	CONTRL 1	CONTRL 2	CONTRL 3
HUB (cfu/g)	NIL	NIL	0.10 X101	0.10 X101	NIL	NIL	NIL	NIL	NIL	NIL	NIL	0.20 X101	NIL	NIL	NIL	NIL	NIL	NIL	NIL
THB (cfu/g)	9.20X 101	1.12 X102	2.17 X102	2.41 X102	2.19 X102	2.11 X102	2.17 X102	2.02 X102	2.01X 102	1.98 X102	2.17 X102	2.36 X102	1.31 X102	2.21 X102	1.92 X102	2.17 X102	2.14X 102	2.28X 102	2.18X 102
THF (cfu/g)	5.80X 101	6.20 X101	9.80 X101	1.14 X102	7.20 X101	7.30 X101	9.30 X101	8.10 X10	1.07X 101	9.50 X101	1.21 X101	9.10 X101	4.60 X101	8.80 X101	8.40 X101	6.20 X10	8.10X 101	9.20X 101	6.10X 101
SRB (cfu/g)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Appendix 2.3.2: Detailed results for Sediment physicochemical and microbiological measurements in the JK Field during wet season

		BLOCK D								BLOCK E						
	200m		500m		800m		1200m		200m		500m		800m		1200m	
Parameters	ASW5	ASW6	SW5	SW6	S3	SW27	S15T	SW39	ASW7	ASW8	SW7	SW8	S4	SW28	S16T	SW40T
pH	7.77	7.82	8.11	8	7.89	7.77	7.87	7.82	7.84	7.85	7.82	7.85	7.93	7.81	7.89	7.74
Redox (mV)	-47.6	-50.9	-68.9	-62.1	-54.7	-48.8	-53.7	-51.6	-52.9	-53.3	-49.8	-53.8	-57.1	-50.6	-54.9	-47
Temp (°C)	15.1	15.5	17.3	16.5	16.7	16.9	16.4	16.3	16.5	17.7	17.2	17.3	17.2	16.5	16.8	16.9
colour	GREY	GREY	GREY	GREY	GREY	GREY	GREY	GREY	GREY	GREY	GREY	GREY	GREY	GREY	GREY	GREY
Cl^- (mg/kg)	10428	9329	9150	9278	9559	9303	4661	9329	9278	10070	8997	8715	8843	9508	9840	9201
TOC (%)	1.02	1.51	0.94	1.86	2.01	1.24	1.77	0.86	2.42	2.15	0.85	0.79	1.24	1.32	1.54	0.21
NO3- (mg/kg)	4.7	4.2	<0.1	1.2	1.8	0.8	0.8	2.8	<0.1	0.8	1.5	1	0.9	<0.1	1.2	5

		BLOCK D								BLOCK E						
	200m		500m		800m		1200m		200m		500m		800m		1200m	
Parameters	ASW5	ASW6	SW5	SW6	S3	SW27	S15T	SW39	ASW7	ASW8	SW7	SW8	S4	SW28	S16T	SW40T
PO_4^{3-} (mg/kg)	0.25	0.31	0.55	0.52	0.16	0.32	0.26	0.49	0.39	0.34	0.05	0.21	0.12	0.21	0.32	0.53
NH_4^+ (mg/kg)	2.19	1.95	<0.01	0.56	0.84	0.37	0.37	1.3	<0.01	0.37	0.69	0.47	0.42	<0.01	0.56	2.33
Sand (%)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Silt (%)	52.63	51.22	48.57	51.4	51.35	47.06	53.85	49.11	50.85	51	48.98	48.84	51.25	48.65	51.82	48.8
Clay (%)	47.36	48.76	51.4	48.58	48.62	52.92	46.11	50.8	49.12	48.97	51	51.15	48.73	51.34	48.16	51.16
THC (mg/kg)	12.5	13.3	6.5	7.9	6.3	13.3	20	5.8	6.7	6.3	14.1	12.5	14.2	12.5	13.3	7.1
TPH (mg/kg)	<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	<0.001	<0.001	<0.001
PAH (mg/kg)	<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	<0.001	<0.001	<0.001
BTEX (mg/kg)	<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	<0.001	<0.001	<0.001
Ni (mg/kg)	15.725	20.821	10.214	98.234	97.231	10.214	56.124	21.325	98.123	46.234	89.123	96.562	68.978	42.125	35.156	42.123
Fe (mg/kg)	7452	7421	7512	7112	7845	8796	7423	7546	7542	7568	6839	7102	8412	8456	7456	10368
Pb (mg/kg)	1.118	1.202	0.224	1.248	<0.001	2.822	0.284	1.214	1.415	1.224	2.247	1.323	1.137	<0.001	1.257	1.961
Cu (mg/kg)	4.673	3.622	9.636	4.234	4.968	4.238	6.573	6.202	6.143	5.681	7.158	2.281	10.223	9.105	5.211	5.972
Cr (mg/kg)	31.213	27.141	22.232	19.703	24.102	3.922	29.377	10.217	28.384	24.199	22.223	18.536	31.116	18.428	19.518	11.168
Zn (mg/kg)	20.422	8.326	20.946	32.275	0.322	16.227	6.351	32.471	12.794	28.175	29.116	20.551	20.472	12.315	9.218	19.452
Cd (mg/kg)	8.231	7.124	4.235	5.532	4.235	2.16	4.125	9.866	5.123	2.103	4.389	3.128	3.289	10.619	3.256	6.012
Ba (mg/kg)	14	11	11	11	13	11	8	12	13	9	6	11	9	8	11	10

		BLOCK D								BLOCK E						
	200m		500m		800m		1200m		200m		500m		800m		1200m	
Parameters	ASW5	ASW6	SW5	SW6	S3	SW27	S15T	SW39	ASW7	ASW8	SW7	SW8	S4	SW28	S16T	SW40T
Co (mg/kg)	8.124	10.234	7.123	6.452	8.459	10.124	10.218	8.124	9.238	6.128	4.231	6.425	8.459	6.127	13.124	10.239
Ag (mg/kg)	<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	<0.001	<0.001	<0.001
V (mg/kg)	<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	<0.001	<0.001	<0.001
K (mg/kg)	527	528	611	541	554	543	664	554	582	545	539	528	529	586	608	590
Na (mg/kg)	11209	11416	12418	11437	11301	12411	12948	12217	11492	11012	11275	11132	11165	12515	12513	12979
Mg (mg/kg)	2713	2497	2522	2586	2321	2231	2598	2252	2838	2918	2392	2135	2342	2492	2563	2428
Ca (mg/kg)	1010	1061	1295	1182	1217	1129	1329	1286	1005	1013	1234	1195	1186	1388	1327	1311
HUF (cfu/g)	NIL	NIL	0.02X 102	NIL	NIL	0.03X 101	NIL	0.13 X 101	NIL	0.03X 102	NIL	NIL	0.33 X 102	0.05X 101	NIL	NIL
HUB (cfu/g)	2.00X 101	0.16X 101	0.15X 101	0.07X 102	0.29X 101	0.24X 101	0.06 X 102	0.24X 101	0.21X 101	0.34X 101	0.19X 101	2.00X 101	0.08X 102	0.17 X 101	0.17X 101	NIL
THB (cfu/g)	0.83X 101	1.10X 102	1.13X 102	2.05X 102	1.30X 102	1.68X 102	0.65X 101	0.66X 101	1.01X 102	0.96X 102	1.38X 102	2.01X 102	1.12X 102	2.07X 102	0.76X 101	1.23X 102
THF (cfu/g)	2.16X 102	2.05X 102	2.06X 102	2.53X 102	2.16X 102	2.07X 102	2.36X 102	0.55X 101	1.83X 102	1.95X 102	2.19X 102	2.56X 102	3.00X 102	2.21X 102	2.18X 102	0.93X 101
SRB (cfu/g)	7.10X 105	7.30X105	5.30X 105	5.40X 105	5.50X 105	8.50X 105	3.20X105	5.40X105	7.00X 105	5.00X 106	8.20X 105	5.50X 105	7.80X106	5.80X105	5.80X 105	8.10X 105

Appendix 2.3.2: Detailed results for Sediment physicochemical and microbiological measurements in the JK Field during wet season Contd.

	BLOCK H								BLOCK C (mini cluster)							
	200m		500m		800m		1200m		200m		500m		800m		1200m	
Parameters	ASW15	ASW16	SW15	SW16	S8	SW32	S20T	SW44T	ASW3	ASW4	SW3	SW4	S2	SW26	S14T	SW38T
pH	7.82	7.75	7.95	7.27	7.83	7.36	7.77	7.6	7.71	7.68	7.64	7.74	7.75	7.86	7.72	7.82
Redox (mV)	-56.6	-47.5	-58.3	-24.3	-51.8	-23.4	-47.8	-31.9	-43.1	-42.6	-40.4	-47.4	-34	-53.4	-45.9	-50.9
Temp (^oC)	17.1	16.2	16.9	16.5	17.2	16.7	16.2	16.2	16.8	16.2	16.5	16.3	17.4	18.1	17.2	18.4
colour	GREY	GREY	GREY	GREY	GREY	GREY	GREY	GREY	GREY	GREY	GREY	GREY	GREY	GREY	GREY	GREY
Cl^- (mg/kg)	9406	8434	9482	8997	9585	9022	8946	9303	9482	9124	9124	9048	9329	9227	9942	9380
TOC (%)	1.59	0.86	2.39	0.87	2.08	0.56	1.09	1.69	1.65	2.16	2.67	1.12	1.88	1.73	0.42	1.35
NO3- (mg/kg)	1.6	2.6	1.2	0.7	0.8	3.6	0.8	2.1	3.2	3.8	0.8	0.2	1.4	1.4	0.4	2
PO_4^{3-} (mg/kg)	0.54	0.34	0.29	0.39	0.24	0.21	0.46	0.13	0.28	0.34	0.52	0.61	0.22	0.42	0.18	0.51
NH_4^+ (mg/kg)	0.74	1.21	0.56	0.33	0.37	1.67	0.37	0.98	1.49	1.77	0.37	0.1	0.65	0.19	0.19	0.93
Sand (%)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Silt (%)	52.63	51.89	48.48	46.18	51.26	52.5	52.28	44.19	51.43	50.94	48.78	47.2	51.06	48.94	51.5	50.9
Clay (%)	47.34	48.1	51.5	53.82	48.72	47.47	47.7	55.8	48.55	49.03	51.2	52.78	48.91	51.04	48.46	49.07
THC (mg/kg)	7.2	14.1	12.5	22.5	14.2	15	13.3	15	6.7	7.5	7.1	13.3	7.5	14.2	7.5	12.5

	BLOCK H								BLOCK C (mini cluster)							
	200m		500m		800m		1200m		200m		500m		800m		1200m	
Parameters	ASW15	ASW16	SW15	SW16	S8	SW32	S20T	SW44T	ASW3	ASW4	SW3	SW4	S2	SW26	S14T	SW38T
TPH (mg/kg)	<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	<0.001	<0.001	<0.001
PAH (mg/kg)	<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	<0.001	<0.001	<0.001
BTEX (mg/kg)	<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	<0.001	<0.001	<0.001
Ni (mg/kg)	10.453	20.458	22.822	20.145	<0.001	89.125	20.123	55.123	78.986	69.897	22.124	10.281	1.028	12.056	75.231	65.231
Fe (mg/kg)	7564	8451	6892	7236	10263	8945	7845	6539	7894	8456	7542	7421	7423	6897	6893	7546
Pb (mg/kg)	<0.001	1.297	2.009	<0.001	1.129	2.273	1.155	1.827	1.327	1.005	1.222	3.224	0.124	1.226	1.211	3.205
Cu (mg/kg)	6.12	5.853	4.128	6.238	5.318	8.24	3.824	6.128	7.192	12.151	5.032	5.289	6.125	2.233	2.673	7.231
Cr (mg/kg)	21.634	20.107	20.314	13.323	30.623	21.912	15.23	31.236	57.542	23.264	3.427	16.294	31.257	5.219	49.924	14.211
Zn (mg/kg)	18.253	26.998	16.758	9.274	63.962	20.183	6.244	19.318	22.326	19.812	20.194	18.211	11.859	36.218	10.473	14.198
Cd (mg/kg)	2.134	6.125	5.914	8.556	3.458	0.238	6.258	0.925	3.031	7.531	8.753	5.656	2.128	0.69	1.234	4.237
Ba (mg/kg)	11	6	9	10	12	10	10	12	16	5	10	8	11	7	12	14

	BLOCK H								BLOCK C (mini cluster)							
	200m		500m		800m		1200m		200m		500m		800m		1200m	
Parameters	ASW15	ASW16	SW15	SW16	S8	SW32	S20T	SW44T	ASW3	ASW4	SW3	SW4	S2	SW26	S14T	SW38T
Co (mg/kg)	8.124	8.679	19.124	14.246	8.459	8.214	10.147	8.359	6.239	10.213	6.489	8.452	6.238	6.421	11.245	7.234
Ag (mg/kg)	<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	<0.001	<0.001	<0.001
V (mg/kg)	<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	<0.001	<0.001	<0.001
K (mg/kg)	525	513	578	541	542	557	561	614	593	552	552	625	548	597	597	526
Na (mg/kg)	11509	11311	12613	12117	11911	12391	11711	13659	11792	11418	11233	12891	11121	13122	12919	11312
Mg (mg/kg)	2447	2318	2492	2228	2213	2261	2487	2472	2723	2571	2618	2573	2410	2497	2335	2151
Ca (mg/kg)	1197	1185	1372	1196	1137	1297	1297	1341	1049	1027	1239	1307	1194	1377	1284	1141
HUF (cfu/g)	NIL	NIL	NIL	0.06X102	0.05X102	NIL	0.03X102	NIL	NIL	0.02X102	0.14X101	0.07X102	0.02X102	0.06X102	0.03X102	0.05X101
HUB (cfu/g)	2.00X101	0.08X101	1.00X101	0.22X101	0.11X101	0.01X102	0.15X101	NIL	0.09X102	0.13X101	0.28X101	0.24X102	0.13X101	0.21X101	0.08X102	0.25X101
THB (cfu/g)	0.91X101	1.22X102	1.86X102	0.96X101	0.73X101	0.57X101	0.93X101	1.34X102	0.88X101	0.72X102	2.11X102	1.24X102	0.72X101	1.55X102	0.93X101	2.08X102
THF (cfu/g)	2.41X102	2.07X102	2.19X102	1.17X102	I.98X102	0.98X101	1.36X102	0.86X101	1.51X102	2.86X102	2.99X102	1.99X102	1.84X101	2.16X102	2.41X102	1.03X101
SRB (cfu/g)	8.10X105	7.50X105	8.30X105	8.20X105	5.00X105	7.40X105	7.30X105	5.30X105	5.90X105	5.50X105	7.80X105	5.50X105	8.30X105	5.00X105	5.50X105	5.70X105

Appendix 2.3.2: Detailed results for Sediment physicochemical and microbiological measurements in the JK Field during wet season Contd.

	BLOCK F								BLOCK G							
	200m		500m		800m		1200m		200m		500m		800m		1200m	
Parameters	ASW9	ASW10	SW9	SW10T	S5	SW29	S17T	SW41T	ASW11	ASW12T	SW11T	SW12	S6T	SW30	S18	SW42T
pH	781	7.81	7.75	7.77	7.79	7.76	7.73	7.82	7.8	7.73	7.78	7.75	7.75	7.18	8.01	7.74
Redox (mV)	-50.6	-50.8	-47.8	-48.5	-49.7	-47.3	-46.5	-47.8	-49	-45.8	-48	-47	-47.3	-42.6	-62.6	-46.4
Temp (°C)	17.4	17	16.8	16.9	16.5	18.3	17.2	17.2	16.5	16.8	17.1	16.5	16.8	16.2	16.6	16.4
colour	GREY	GREY	GREY	GREY	GREY	GREY	GREY	GREY	GREY	GREY	GREY	GREY	GREY	GREY	GREY	GREY
Cl^- (mg/kg)	8971	9815	8792	8869	8690	9457	9891	9150	9457	9176	9227	8894	9610	9303	9048	9176
TOC (%)	0.64	2.04	1.87	0.47	0.87	1.61	1.76	3.02	1.11	0.63	0.87	2.94	1.29	3.05	3.09	0.42
NO3- (mg/kg)	2.7	2.4	<0.1	0.2	0.6	2.8	1.6	5.4	0.1	<0.1	0.4	0.6	<0.1	3.1	0.9	4.4
PO_4^{3-} (mg/kg)	0.56	0.49	0.17	0.24	0.09	0.34	0.38	0.54	0.64	0.68	0.29	0.34	0.04	0.48	0.42	0.46
NH_4^+ (mg/kg)	1.26	1.17	<0.01	0.1	0.28	1.3	0.74	2.51	1.44	<0.01	0.19	0.28	<0.01	1.44	0.42	2.05
Sand (%)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Silt (%)	51.04	48.7	48.78	51.52	53.66	47.2	51.39	51.35	51.16	53.57	46.67	47.5	51.02	51.28	53.19	52.38
Clay (%)	48.94	51.26	51.2	48.44	46.31	52.76	48.6	48.62	48.81	46.41	53.3	52.46	48.95	48.7	48.8	47.6
THC (mg/kg)	14.1	12.5	15	20.1	13.3	7.5	12.5	13.3	7	7.9	6.7	15.8	14.2	7.1	13.3	12.5

	BLOCK F								BLOCK G							
	200m		500m		800m		1200m		200m		500m		800m		1200m	
Parameters	ASW9	ASW10	SW9	SW10T	S5	SW29	S17T	SW41T	ASW11	ASW12T	SW11T	SW12	S6T	SW30	S18	SW42T
TPH (mg/kg)	0.08	<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	<0.001	<0.001
PAH (mg/kg)	<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	<0.001	<0.001	<0.001
BTEX (mg/kg)	<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	<0.001	<0.001	<0.001
Ni (mg/kg)	<0.001	58.865	78.125	55.218	53.231	76.123	32.125	36.128	48.23	70.458	42.127	35.124	125.356	65.231	22.234	32.421
Fe (mg/kg)	10541	7456	7125	7423	7451	8569	7895	7569	8456	8645	7123	7125	7658	7452	7423	7845
Pb (mg/kg)	0.637	1.317	0.927	1.244	1.122	1.298	1.234	3.182	1.421	<0.001	1.845	0.996	<0.001	1.153	1.987	2.227
Cu (mg/kg)	7.293	10.214	9.234	6.168	6.311	3.234	4.519	5.211	3.119	3.237	9.347	9.42	4.754	5.166	5.238	2.419
Cr (mg/kg)	27.316	30.533	12.215	10.234	19.197	0.164	28.231	16.214	31.133	28.531	14.226	9.413	27.319	10.193	20.112	14.316
Zn (mg/kg)	<0.001	2.386	35.437	41.611	12.638	20.826	11.063	11.393	22.557	29.82	12.514	19.205	7.536	15.372	9.548	13.569
Cd (mg/kg)	3.124	0.738	<0.001	1.258	3.568	8.401	2.123	5.126	5.132	1.024	2.28	5.124	5.236	13.258	4.568	10.234
Ba (mg/kg)	12	6	8	7	12	10	11	9	6	10	8	16	10	5	15	10

	BLOCK F								BLOCK G							
	200m		500m		800m		1200m		200m		500m		800m		1200m	
Parameters	ASW9	ASW10	SW9	SW10T	S5	SW29	S17T	SW41T	ASW11	ASW12T	SW11T	SW12	S6T	SW30	S18	SW42T
Co (mg/kg)	7.126	5.234	12.124	10.124	8.125	8.124	8.459	8.456	8.124	9.125	6.231	5.217	8.124	9.124	13.127	10.234
Ag (mg/kg)	<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	<0.001	<0.001	<0.001
V (mg/kg)	<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	<0.001	<0.001	<0.001
K (mg/kg)	558	565	534	565	521	524	544	527	522	581	542	529	529	611	592	601
Na (mg/kg)	11163	11172	11276	12383	11253	11822	11814	11206	11471	11233	12132	11165	11414	13937	12813	13852
Mg (mg/kg)	2792	2516	2213	2281	2317	2264	2317	2132	2313	2298	2397	2143	2342	2486	2411	2413
Ca (mg/kg)	1032	1072	1211	1217	1126	1134	1258	1147	1042	1074	1221	1224	1129	1394	1318	1322
HUF (cfu/g)	0.22X101	NIL	0.02X102	0.05X102	0.06 X 102	0.16X101	0.03X102	NIL	0.04X102	0.08X102	0.05X102	NIL	0.04X102	NIL	0.17X101	NIL
HUB (cfu/g)	0.14X101	0.08X102	0.18X101	0.26X101	0.18X101	0.11X101	1.00X101	NIL	0.15X101	1.00X101	0.15X101	0.06X102	0.12X101	0.05X101	0.06X102	0.01X101
THB (cfu/g)	1.21X102	1.43X102	1.21X102	1.93X102	0.69X101	1.86X102	1.03X102	1.27X102	0.83X101	0.61X101	1.28X102	1.16X102	0.77X101	1.09X102	0.75X102	1.09X102
THF (cfu/g)	1.71X102	2.03X102	2.02X102	2.63X102	2.06X102	0.92X101	2.09X102	0.83X101	209X102	1.98X102	2.66X102	1.20X102	1.56X102	0.69X101	2.65X102	1.01X101
SRB (cfu/g)	5.50X105	8.40X105	4.30X105	5.80X105	5.70X105	7.40X105	8.00X105	7.40X105	5.80X105	5.80X105	5.70X105	7.40X105	5.10X105	5.40X105	5.30X105	5.80X105

Appendix 2.3.2: Detailed results for Sediment physicochemical and microbiological measurements in the JK Field during wet season Contd.

	BLOCK I								BLOCK A							
	200m		500m		800m		1200m		200m		500m		800m		1200m	
Parameters	ASW19	ASW20	SW19T	SW20	S10	SW34	S22T	SW46T	ASW1	ASW2	SW1	SW2	S1	SW25	S13T	SW37T
pH	7.76	7.81	7.91	7.56	7.76	7.53	7.76	7.74	7.64	7.67	7.67	7.68	7.66	7.78	7.71	7.76
Redox (mV)	-46.9	-50.9	-56.1	39.7	-48.7	-36.5	-48.4	-46.9	-41.8	-43.3	-44.1	-44.2	-42.7	-49.2	-46.1	-47.8
Temp (^oC)	16.5	16.9	18.2	16.4	16.8	16.8	17.1	16.7	15.8	16.5	16.2	16.3	16.8	16.5	16.1	16.5
colour	GREY	GREY	GREY	GREY	GREY	GREY	GREY	GREY	GREY	GREY	GREY	GREY	GREY	GREY	GREY	GREY
Cl^- (mg/kg)	9917	8562	8869	9201	9380	8971	9380	9457	9917	9252	9303	9533	10914	9048	9559	9431
TOC (%)	1.85	2.64	1.58	1.59	1.29	1.63	1.64	1.61	1.12	0.42	2.29	1.35	1.04	1.1	2.84	0.83
NO3- (mg/kg)	1.4	2.7	1.8	2.1	2.8	1.5	4.1	2.4	0.3	2.7	<0.1	0.2	1	2.6	0.2	1.2
PO_4^{3-} (mg/kg)	0.38	0.52	0.4	0.39	0.46	0.29	0.42	0.09	0.33	0.23	0.21	0.3	0.27	0.56	0.11	0.64
NH_4^+ (mg/kg)	0.65	1.26	0.84	0.01	1.3	0.7	1.91	1.12	0.14	0.26	<0.01	0.1	0.47	1.21	0.1	0.56
Sand (%)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Silt (%)	52.78	52.94	48.39	47.7	52.17	51.79	52.5	45.15	51.08	51.16	48.28	48.98	53.66	48.72	51.22	51.06
Clay (%)	47.2	47.04	51.6	52.27	47.8	48.2	47.46	54.84	48.95	48.83	51.7	51.01	46.32	51.26	48.76	48.92
THC (mg/kg)	6.7	7.5	12.5	17.5	12.5	7.5	15.8	15.8	7.5	7.1	7.5	7.9	13.3	22.5	13.3	12.5

	BLOCK I								BLOCK A							
	200m		500m		800m		1200m		200m		500m		800m		1200m	
Parameters	ASW19	ASW20	SW19T	SW20	S10	SW34	S22T	SW46T	ASW1	ASW2	SW1	SW2	S1	SW25	S13T	SW37T
TPH (mg/kg)	<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	<0.001	0.05	<0.001
PAH (mg/kg)	<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	<0.001	<0.001	<0.001
BTEX (mg/kg)	<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	<0.001	<0.001	<0.001
Ni (mg/kg)	35.264	36.489	30.248	26.128	38.243	<0.001	72.315	43.111	15.531	26.895	89.125	26.885	1.321	26.124	56.248	35.087
Fe (mg/kg)	7546	8451	7589	7425	7423	6847	7689	7456	8546	7986	8745	7542	8112	8691	6598	8645
Pb (mg/kg)	<0.001	0.918	1.718	0.129	1.229	1.242	2.334	2.202	1.153	0.153	<0.001	<0.001	1.476	1.129	0.915	1.448
Cu (mg/kg)	6.181	5.322	3.234	4.393	10.051	5.31	5.107	2.848	9.119	4.558	6.234	8.04	9.218	6.356	2.118	6.218
Cr (mg/kg)	<0.001	21.113	10.315	9.317	27.192	32.226	15.173	11.874	41.823	28.437	16.337	9.041	36.281	2.181	59.167	13.206
Zn (mg/kg)	<0.001	<0.001	12.084	9.451	15.662	20.739	20.519	12.541	<0.001	20.218	22.664	15.937	<0.001	39.633	35.186	20.104
Cd (mg/kg)	6.787	4.231	3.265	6.125	2.345	4.559	6.278	6.234	5.123	4.235	4.715	<0.001	3.025	2.18	2.456	6.234
Ba (mg/kg)	12	7	15	8	6	18	12	7	8	5	15	6	8	8	10	6

	BLOCK I								BLOCK A							
	200m		500m		800m		1200m		200m		500m		800m		1200m	
Parameters	ASW19	ASW20	SW19T	SW20	S10	SW34	S22T	SW46T	ASW1	ASW2	SW1	SW2	S1	SW25	S13T	SW37T
Co (mg/kg)	10.234	10.345	6.324	8.452	7.423	10.124	9.245	8.452	6.235	8.128	8.421	10.234	8.945	6.123	13.12	6.234
Ag (mg/kg)	<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	<0.001	<0.001	<0.001
V (mg/kg)	<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	<0.001	<0.001	<0.001
K (mg/kg)	552	527	563	549	561	521	525	557	526	581	693	598	602	599	621	542
Na (mg/kg)	11015	11271	12159	12612	12207	11151	11327	12458	12014	11316	12925	12716	13851	12951	13952	12913
Mg (mg/kg)	2357	2211	2511	2285	2282	2122	2198	2284	2993	2847	2584	2463	2439	2518	2492	2243
Ca (mg/kg)	1185	1174	1258	1186	1189	1115	1128	1283	1093	1052	1321	1313	1398	1332	1321	1253
HUF (cfu/g)	0.11X 101	0.02X 102	0.02X 102	0.11 X 101	0.03X 102	NIL	NIL	NIL	NIL	0.07X 101	0.22X 101	0.14X 101	0.14X 101	NIL	NIL	0.02 X 101
HUB (cfu/g)	0.18X 101	0.14X 101	0.19X 101	0.32X101	0.23X 101	NIL	0.07X 101	0.02X 101	0.07X 102	0.11X 101	0.36X 101	0.38X 101	0.15X 101	0.12X 101	0.11X 101	0.12X 101
THB (cfu/g)	0.96X 101	0.88X 101	1.75X 102	1.85X 102	0.58X 101	1.22X 102	0.81X 101	2.17X 101	1.17X 102	1.19X 102	1.89X 102	2.03X 102	1.01X 102	1.93X 102	0.86X 101	2.19X 102
THF (cfu/g)	2.17X 102	2.85X 102	2.14X 102	2.03X 102	1.89X 102	0.71X 101	2.05X 102	1.03X 101	3.00X 102	2.06X 102	2.85X 102	2.40X 102	2.54X 102	2.93X 102	2.19X 102	1.12X 102
SRB (cfu/g)	7.40X105	5.10X105	5.20X106	5.50X105	8.80X106	3.30X105	5.30X105	7.50X105	5.30X105	5.20X105	5.10X105	8.20X106	7.80X105	7.50X105	5.40X105	5.50X105

Appendix 2.3.2: Detailed results for Sediment physicochemical and microbiological measurements in the JK Field during wet season Contd.

	BLOCK J								BLOCK GS							
	200m		500m		800m		1200m		200m		500m		800m		1200m	
Parameters	ASW21	ASW22	SW21	SW22	S11	SW35	S23T	SW47T	ASW13	ASW14	SW13	SW14	S7	SW31	S19T	SW43T
pH	7.76	7.75	7.69	7.72	6.98	7.84	7.69	7.76	7.73	7.88	8.19	7.76	7.94	7.78	7.82	7.72
Redox (mV)	-48.4	-47.4	-44	-46.1	-15.4	-52.4	-44	-48.9	-52.6	-54.4	-65.4	-49.4	-57.9	-55.4	-51.4	-45.4
Temp (^oC)	16.3	16.9	17.2	16.5	16.5	16.6	16.2	17.6	16.5	16.2	16.3	16.2	16.6	17.4	15.9	17.3
colour	GREY	GREY	GREY	GREY	GREY	GREY	GREY	GREY	GREY	GREY	GREY	GREY	GREY	GREY	GREY	GREY
Cl^- (mg/kg)	8230	9278	9048	9278	8383	9508	9048	9815	8946	8741	9329	9176	8920	9150	9227	9227
TOC (%)	1.61	2.41	1.81	0.93	0.85	1.23	1.11	2.42	2.01	2.45	3.13	1.55	<0.01	0.86	2.13	1.63
NO3- (mg/kg)	<0.1	0.2	1.8	2	2.6	1.8	4.2	0.5	0.3	<0.1	0.8	0.6	<0.1	2.8	0.6	4.1
PO_4^{3-} (mg/kg)	0.53	0.58	0.58	0.52	0.31	0.73	0.51	0.07	0.62	0.51	0.26	0.22	0.14	0.41	0.48	0.36
NH_4^+ (mg/kg)	<0.01	0.09	0.84	0.93	1.21	0.84	1.95	0.23	0.14	<0.01	0.37	0.28	<0.01	1.3	0.28	1.91
Sand (%)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Silt (%)	51.06	52.94	47.5	48	52.93	51.9	54.54	46.9	47.5	51.61	47.22	45.97	51.1	51.52	51.3	48.38
Clay (%)	48.93	47.07	52.46	51.97	47.05	48.08	45.44	52.97	52.47	48.37	52.76	53.89	48.86	48.46	46.67	51.6
THC (mg/kg)	7.5	7.5	15	11.7	15.8	14.2	15.8	6.3	14.1	7	12.5	15	5.8	14.2	11.7	6.3

	BLOCK J								BLOCK GS							
	200m		500m		800m		1200m		200m		500m		800m		1200m	
Parameters	ASW21	ASW22	SW21	SW22	S11	SW35	S23T	SW47T	ASW13	ASW14	SW13	SW14	S7	SW31	S19T	SW43T
TPH (mg/kg)	<0.001	0.04	<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	<0.001
PAH (mg/kg)	<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	<0.001	<0.001	<0.001
BTEX (mg/kg)	<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	<0.001	<0.001	<0.001
Ni (mg/kg)	8.402	40.289	<0.001	26.128	40.231	<0.001	14.554	32.128	65.458	47.234	28.145	52.129	26.231	56.128	<0.001	20.245
Fe (mg/kg)	7654	7421	7598	7563	7643	12043	7845	6897	7568	7451	10824	7235	8412	6852	8456	7845
Pb (mg/kg)	0.301	1.153	2.411	1.544	1.241	<0.001	1.714	1.123	0.974	1.132	1.217	1.814	1.263	3.115	2.233	3.114
Cu (mg/kg)	8.224	5.183	8.015	4.639	7.425	9.154	2.965	4.117	5.423	8.215	6.131	5.774	6.327	6.133	2.957	5.756
Cr (mg/kg)	20.112	24.161	3.224	6.127	28.243	41.215	9.225	12.311	33.229	21.194	9.128	36.112	28.271	5.382	24.181	9.255
Zn (mg/kg)	3.016	98.784	10.472	18.482	<0.001	15.489	47.057	16.119	<0.001	4.936	12.337	14.408	30.185	22.769	5.395	20.272
Cd (mg/kg)	2.315	3.128	5.324	7.238	2.11	5.084	4.235	8.127	2.189	3.125	4.235	4.295	4.368	10.234	3.589	9.234
Ba (mg/kg)	9	6	6	10	11	11	9.7	14	5	9	5	7	6	6	13	140

	BLOCK J								BLOCK GS							
	200m		500m		800m		1200m		200m		500m		800m		1200m	
Parameters	ASW21	ASW22	SW21	SW22	S11	SW35	S23T	SW47T	ASW13	ASW14	SW13	SW14	S7	SW31	S19T	SW43T
Co (mg/kg)	12.145	9.458	13.451	13.124	10.211	8.124	12.423	10.249	6.124	8.124	7.235	8.124	6.124	8.452	12.145	11.238
Ag (mg/kg)	<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	<0.001	<0.001	<0.001
V (mg/kg)	<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	<0.001	<0.001	<0.001
K (mg/kg)	537	552	545	561	590	544	563	564	531	522	617	598	569	548	534	577
Na (mg/kg)	11098	11142	12318	12213	12472	12411	12216	12653	11352	11131	12822	12732	12161	12251	11261	13112
Mg (mg/kg)	2175	2298	2257	2276	2518	2242	2295	2297	2327	2343	2563	2503	2423	2265	2372	2393
Ca (mg/kg)	1098	1193	1161	1219	1211	1169	1224	1286	1121	1113	1471	1421	1271	1201	1195	1286
HUF (cfu/g)	NIL	0.02X 102	0.01X 102	NIL	0.03X 102	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL
HUB (cfu/g)	0.07X 102	0.16X 101	0.09X 101	0.06X 102	0.09X 102	NIL	0.21 X 101	NIL	0.06X 102	0.08X 102	0.14X 101	0.08 X 102	0.07X 102	NIL	NIL	NIL
THB (cfu/g)	1.75X 102	1.03X 102	2.16X 102	1.92X 101	0.64X 101	1.13X 102	0.77X 101	2.27X 102	2.13X 102	1.96X 102	1.57X 102	1.34X 102	0.68X 101	1.29X 102	0.92X 101	219X 102
THF (cfu/g)	2.16X 102	2.25X 102	1.17X 102	0.72X 101	2.99X 102	0.84X 101	2.54X 102	1.19X 102	2.02X 102	1.89X 102	2.01X 102	1.83X 102	0.98X 102	0.66X 101	2.56X 101	0.92X 101
SRB (cfu/g)	7.10X 105	5.20X 105	8.20X 105	7.30X 105	8.40X 105	7.00X 105	5.00X105	7.80X 105	5.10X105	5.50X 105	7.70X 105	5.50X105	7.30X 105	5.20X 105	5.10X 105	3.50X 105

Appendix 2.3.2: Detailed results for Sediment physicochemical and microbiological measurements in the JK Field during wet season Contd.

	BLOCK K								BLOCK HE										
	200m		500m		800m		1200m		200m		500m		800m		1200m				
Parameters	ASW23	ASW24	SW23	SW24	S12	SW36	S24T	SW48T	ASW17	ASW18	SW17	SW18T	S9	SW33	S21T	SW45T	CONTRL1	CONTRL2	CONTRL3
pH	7.75	7.86	7.71	7.82	7.84	7.73	7.79	7.88	7.74	7.769	7.6	7.71	7.37	7.63	7.58	7.42	8.03	8.01	7.5
Redox (mV)	-47.4	-53.5	-46.4	-50.5	-51.6	-46	-49.3	-55.9	-33.8	-33.8	-31.6	-33.9	-22.9	-30.4	-31.6	-23.6	-63.8	-61.5	-36.3
Temp (^{o}C)	16.9	17.2	16.3	16.8	16.3	17.2	16.4	18.3	17.4	16.7	17.2	16.5	16.5	16.3	16.3	16.8	17.8	20.8	19.3
colour	GREY	GREY	GREY	GREY	GREY	GREY	GREY	GREY	GREY	GREY	GREY	GREY	GREY	GREY	GREY	GREY	GREY	GREY	GREY
Cl^- (mg/kg)	9278	8485	9457	9227	9457	9303	8920	9917	8537	9022	9329	8715	8639	9201	9329	9406	9048	9763	9329
TOC (%)	2.41	2.53	1.65	2.11	1.87	1.36	1.02	0.65	3.05	2.75	1.11	0.42	1.34	2.41	1.47	1.83	0.87	1.11	1.08
NO3- (mg/kg)	0.2	3.6	2.4	2.8	<0.1	1.6	4.5	0.8	1.3	1.8	0.8	1.4	3.3	7.7	0.6	2.8	<0.1	2	<0.1
PO_4^{3-} (mg/kg)	0.58	0.36	0.64	0.53	0.15	0.68	0.42	0.12	0.28	0.31	0.41	0.46	0.4	0.18	0.34	0.1	0.31	0.4	0.8
NH_4^+ (mg/kg)	0.09	1.67	1.12	1.3	<0.01	0.74	2.1	0.37	0.6	0.83	0.37	0.56	1.53	3.58	0.28	1.3	<0.01	0.93	<0.01
Sand (%)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Silt (%)	52.94	51.43	46.51	46.06	52.17	50.34	52.17	43.38	51.7	51.35	47.52	47.27	52.26	51.35	51.28	43.9	73.74	19.5	25.64
Clay (%)	47.07	48.53	53.47	53.92	47.8	49.65	47.8	56.61	48.26	48.62	52.45	52.7	47.69	48.63	48.7	56	26.24	80.48	74.33

	BLOCK K								BLOCK HE										
	200m		500m		800m		1200m		200m		500m		800m		1200m				
Parameters	ASW23	ASW24	SW23	SW24	S12	SW36	S24T	SW48T	ASW17	ASW18	SW17	SW18T	S9	SW33	S21T	SW45T	CONTRL1	CONTRL2	CONTRL3
THC (mg/kg)	7.5	15	15	14.2	21.3	6.7	15	15	13.3	6.3	20	7.5	13.3	15	7.5	7.1	15	7.1	6.7
TPH (mg/kg)	0.04	<0.001	<0.001	<0.001	0.11	<0.001	0.04	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
PAH (mg/kg)	<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	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
BTEX (mg/kg)	<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	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Ni (mg/kg)	40.289	32.421	30.281	16.284	36.451	43.128	58.56	22.356	110.234	65.897	26.489	18.124	46.265	40.289	30.12	33.215	20.124	23.456	19.128
Fe (mg/kg)	7421	7642	7569	7456	7765	7512	8974	7456	7546	8456	7126	8612	7125	7532	7845	7512	7489	7845	8456
Pb (mg/kg)	1.153	1.118	1.151	2.367	1.248	2.937	1.864	1.627	0.312	1.612	0.663	<0.001	1.554	1.215	1.749	3.021	20.531	18.122	21.741
Cu (mg/kg)	5.183	6.328	5.187	4.643	3.924	8.237	4.961	2.154	3.927	4.332	5.128	7.235	9.284	11.102	2.553	4.403	0.352	0.924	1.103
Cr (mg/kg)	24.161	28.314	5.253	3.134	31.314	14.164	11.18	6.011	18.121	17.263	19.329	10.128	44.24	19.186	12.361	8.927	<0.001	<0.001	<0.001
Zn (mg/kg)	98.784	26.361	10.114	12.239	22.669	11.241	25.392	11.438	30.664	30.849	12.116	14.221	1.21	17.524.	10.117	13.655	3.911	10.843	8.227

	BLOCK K								BLOCK HE										
	200m		500m		800m		1200m		200m		500m		800m		1200m				
Parameters	ASW23	ASW24	SW23	SW24	S12	SW36	S24T	SW48T	ASW17	ASW18	SW17	SW18T	S9	SW33	S21T	SW45T	CONTRL1	CONTRL2	CONTRL3
Cd (mg/kg)	3.128	2.056	4.235	6.128	3.128	4.789	6.123	10.235	7.125	7.256	9.123	<0.001	1.751	11.234	5.238	3.245	2.191	<0.001	<0.001
Ba (mg/kg)	6	6	8	5	8	8	11	9	9	11	12	8	9	14	16	8	16	8	12
Co (mg/kg)	9.458	12.234	10.214	8.214	11.321	14.213	9.568	9.369	11.243	9.875	16.231	10.247	8.459	6.124	7.456	10.754	13.284	12.412	10.235
Ag (mg/kg)	<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	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
V (mg/kg)	<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	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
K (mg/kg)	552	523	582	528	528	538	553	548	529	554	611	562	527	522	554	544	618	631	590
Na (mg/kg)	11142	11613	12771	11169	11208	11361	11211	12864	11752	11295	12513	12311	11305	11123	11281	12856	13729	13922	13327
Mg (mg/kg)	2298	2209	2492	2115	2125	2221	2171	2291	2424	2295	2522	2249	2251	2142	2269	2273	2488	2512	2617
Ca (mg/kg)	1193	1112	1288	1128	1142	1173	1243	1283	1181	1198	1391	1212	1143	1157	1253	1264	1373	1398	1322
HUF (cfu/g)	0.02 X 102	NIL	0.02 X 102	0.02 X 102	NIL	NIL	NIL	0.12 X 101	NIL	NIL	0.04 X 102	NIL	NIL	NIL	0.28 X 101	NIL	0.37X 101	0.37X 101	0.28X 101

	BLOCK K								BLOCK HE										
	200m		500m		800m		1200 m		200m		500m		800m		1200 m				
Parameters	ASW 23	ASW 24	SW2 3	SW2 4	S12	SW3 6	S24T	SW4 8T	ASW1 7	ASW 18	SW1 7	SW1 8T	S9	SW3 3	S21T	SW4 5T	CON TRL 1	CON TRL 2	CON TRL 3
HUB (cfu/g)	0.16 X 101	0.22 X 101	0.18 X101	0.21 X101	0.31 X 101	NIL	0.14 X 101	0.38 X 101	0.16X 101	1.00 X 101	0.18 X 101	1.00 X101	0.22 X 101	NIL	0.03 X 102	NIL	0.22X 101	0.22X 101	0.18X 101
THB (cfu/g)	1.03 X 102	1.11 X 102	1.21 X 102	2.09 X 102	0.84 X 101	2.11 X 102	0.92 X 101	0.82 X 101	1.87X 102	2.08 X 102	2.07 X 102	1.85 X 102	1.21 X 102	1.92 X 102	0.64 X 101	2.16 X 102	0.82X 101	0.65X 101	1.01X 102
THF (cfu/g)	2.25 X 102	2.01 X 102	0.56 X 101	0.83 X 101	2.51 X 102	0.98 X 101	3.00 X 102	0.77 X 101	2.31X 102	2.17 X 102	2.41 X 102	2.26 X 102	1.11 X 102	0.81 X 101	2.71 X 102	1.13 X 102	0.86X 101	1.36X 102	1.45X 102
SRB (cfu/g)	5.20 X105	5.50 X105	5.10 X105	4.80 X105	7.20 X105	5.10 X106	8.70 X105	5.90 X105	5.90X 106	8.30 X105	7.50 X105	8.50 X105	7.20 X105	4.50 X105	7.70 X105	5.10 X105	4.40X 106	8.40X 105	5.10X 105

Appendix 2.4: Detailed results for Phytoplankton in the JK Field during

Phytoplankton Species	SW1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Coscinodiscus centralis	5	3	5	0	13	5	7	5	2	0	5	8	0	0	5
Coscinodiscus minor	8	2	10	4	7	8	2	0	0	3	0	6	0	2	0
Cosmioneis sp.	2	5	5	5	8	0	0	0	0	0	8	3	8	0	0
Cyclotella spp	0	0	8	4	3	0	5	7	0	1	0	11	0	12	0
Craticula sp.	5	3	5	6	12	10	0	0	8	5	0	9	3	2	5
Diatoma sp.	6	5	3	11	13	6	0	0	5	0	0	0	0	0	0
Diploneis vagabuda	3	0	9	10	5	7	9	13	8	3	8	6	9	10	0
Entomoneis sp.	5	4	0	6	0	0	0	5	3	0	0	0	0	0	0
Grammatophora marina	0	2	0	0	0	0	0	8	12	0	0	0	0	0	0
Gyrosigma balticum	0	5	0	0	0	0	0	3	0	0	0	0	0	0	3
Gyrosigma peisonis	0	8	3	0	0	0	0	12	0	0	0	0	0	0	0

Phytoplankton Species	SW1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Mastogloia exilis	8	5	7	0	0	0	0	13	0	0	0	0	0	0	0
Mastogloia paradoxa	3	2	0	4	6	8	0	0	0	0	0	0	0	0	0
Navicula spp.	0	0	9	5	8	0	0	0	0	0	0	0	0	0	0
Nitzchia spectabilis	0	0	6	4	3	11	0	4	7	8	0	0	0	0	0
Nitzchia nitzcloidea	0	9	8	6	12	10	0	5	8	0	0	0	0	0	0
Oestrupia zanardiniana	0	5	5	0	0	0	0	4	3	11	0	0	0	3	8
Pleurosigma spp.	7	5	0	0	0	0	0	0	0	0	0	0	0	0	0
Pseudonitzchia spp.	8	7	0	0	0	0	0	0	0	0	0	0	0	0	0
Rhabdonema punctatum	6	5	0	0	0	0	0	0	0	0	0	0	0	0	0
Skeletonema sp.	8	8	0	7	5	0	0	8	8	0	0	0	3	1	8
Synedra spp.	5	8	4	0	0	8	8	0	0	8	7	12	0	0	0
Surirella fastuosa	9	5	9	0	7	5	0	0	0	0	8	8	0	0	0
Sub Total	88	96	96	72	102	78	31	87	64	39	36	63	23	30	29
Prorocentrium sp.	10	8	8	0	0	0	0	7	5	0	0	3	1	8	0
Total	98	104	104	72	102	78	31	94	69	39	36	66	24	38	29
Total Number of Speies	15	20	16	12	13	10	5	13	11	7	5	9	5	7	5

Appendix 2.4: Detailed results for Phytoplankton in the JK Field during Contd.

	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Coscinodiscus centralis	0	3	2	1	0	3	0	4	0	0	0	0	0	0	0
Coscinodiscus minor	5	0	4	6	0	0	9	11	0	0	12	0	0	11	10
Cosmioneis sp.	0	0	0	5	4	8	0	0	0	0	0	0	7	0	3
Cyclotella spp	4	0	2	0	1	0	1	0	2	3	0	4	4	0	4
Craticula sp.	0	7	4	7	0	0	0	0	5	0	4	0	2	0	3
Diatoma sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
Diploneis vagabuda	0	0	0	0	3	8	6	12	10	0	0	0	3	18	6
Entomoneis sp.	0	0	0	0	5	0	3	2	1	0	3	0	0	0	0
Grammatophora marina	0	0	0	0	0	5	0	3	2	1	0	3	0	0	0

	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Gyrosigma balticum	2	5	0	7	4	0	0	0	0	3	2	5	0	7	4
Gyrosigma peisonis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mastogloia exilis	0	0	0	0	5	0	3	2	1	0	3	0	0	0	0
Mastogloia paradoxa	0	0	0	0	3	6	4	1	3	0	0	0	0	0	0
Navicula spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nitzchia spectabilis	0	0	0	0	0	0	0	0	0	0	0	3	18	6	12
Nitzchia nitzcloidea	0	0	0	0	0	0	0	0	0	0	0	5	0	3	2
Oestrupia zanardiniana	6	12	10	0	0	0	0	0	0	0	0	0	0	0	0
Pleurosigma spp.	0	0	0	0	0	3	2	1	0	3	0	5	0	4	0
Pseudonitzchia spp.	0	0	0	0	0	0	5	2	6	0	5	7	0	2	0
Rhabdonema punctatum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Skeletonema sp.	0	0	0	0	5	8	4	0	8	8	12	0	0	0	0
Synedra spp.	0	8	7	12	0	0	0	0	0	0	0	0	0	8	8
Surirella fastuosa	0	0	0	0	0	0	0	0	5	8	4	0	0	0	0
Sub Total	17	35	29	38	30	41	37	38	43	26	45	32	34	59	56
Prorocentrium sp.	0	0	0	5	8	4	0	0	0	0	8	8	12	0	0
Total	17	35	29	43	38	45	37	38	43	26	53	40	46	59	56
Total Number of Speies	4	5	6	7	9	8	9	9	10	6	9	8	6	8	10

Appendix 2.4: Detailed results for Phytoplankton in the JK Field during Contd.

	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45
Coscinodiscus centralis	0	0	0	0	0	0	0	0	6	9	10	4	8	0	0
Coscinodiscus minor	13	8	0	0	0	3	7	3	0	4	8	0	6	5	2
Cosmioneis sp.	5	0	0	0	0	4	6	4	0	0	0	0	0	0	6
Cyclotella spp	2	4	4	6	7	8	0	0	0	0	0	0	4	6	8
Craticula sp.	0	6	0	0	7	5	11	0	0	0	0	10	6	0	9
Diatoma sp.	4	6	7	8	0	0	4	2	4	4	6	7	0	0	0
Diploneis vagabuda	12	10	0	0	0	0	0	4	4	6	7	8	0	0	0
Entomoneis sp.	0	0	11	10	13	8	0	0	0	0	0	0	4	4	6

	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45
Grammatophora marina	0	0	0	0	0	0	4	4	6	7	8	0	0	0	0
Gyrosigma balticum	4	6	7	8	0	0	0	0	0	0	0	0	0	0	0
Gyrosigma peisonis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mastogloia exilis	0	0	0	0	0	0	0	0	0	0	0	0	4	2	4
Mastogloia paradoxa	0	0	0	0	0	0	0	11	10	13	8	0	0	0	0
Navicula spp.	4	4	6	7	8	0	0	0	0	0	0	0	0	0	0
Nitzchia spectabilis	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nitzchia nitzcloidea	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oestrupia zanardiniana	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pleurosigma spp.	6	0	4	0	0	5	0	2	0	0	0	0	6	0	0
Pseudonitzchia spp.	0	2	0	3	5	4	0	0	0	0	2	0	5	0	0
Rhabdonema punctatum	0	0	0	0	0	6	4	1	0	0	0	0	0	0	0
Skeletonema sp.	0	0	0	0	0	4	4	6	7	8	0	0	0	0	0
Synedra spp.	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Surirella fastuosa	0	3	6	4	1	3	0	0	0	0	0	0	0	0	0
Sub Total	73	49	45	46	41	50	40	37	37	51	49	29	43	17	35
Prorocentrium sp.	0	0	4	4	6	7	8	0	0	0	0	0	0	0	0
Total	73	49	49	50	47	57	48	37	37	51	49	29	43	17	35
Total Number of Species	11	9	8	8	7	11	8	9	6	7	7	4	8	4	6

Appendix 2.4: Detailed results for Phytoplankton in the JK Field during Contd.

	46	47	48	49	50	SW51	52	53	54	55	56	57	58	59	60
Coscinodiscus centralis	0	0	0	3	2	5	3	5	0	6	7	4	5	0	0
Coscinodiscus minor	2	0	4	0	1	8	2	3	2	0	1	3	8	0	0
Cosmioneis sp.	1	3	4	6	6	2	5	3	0	0	0	0	0	6	0
Cyclotella spp	4	0	0	0	8	3	0	0	5	3	6	1	3	0	4
Craticula sp.	0	0	0	3	0	0	3	8	0	4	0	0	5	0	0
Diatoma sp.	0	0	0	0	5	0	5	5	0	0	0	2	0	3	5
Diploneis vagabuda	6	5	2	2	0	0	0	8	0	0	4	0	0	0	0

	46	47	48	49	50	SW51	52	53	54	55	56	57	58	59	60
Entomoneis sp.	7	8	0	0	0	5	4	2	1	3	2	0	8	0	6
Grammatophora marina	0	0	0	0	0	6	2	0	0	0	0	0	6	8	0
Gyrosigma balticum	0	0	0	0	0	4	0	8	0	0	0	0	4	0	5
Gyrosigma peisonis	0	0	0	0	0	9	8	4	0	0	0	0	2	0	3
Mastogloia exilis	4	6	0	0	0	0	0	0	0	0	0	0	8	2	0
Mastogloia paradoxa	0	0	0	0	0	0	0	0	0	0	0	0	3	0	5
Navicula spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8
Nitzchia spectabilis	0	0	0	0	0	0	0	0	0	0	0	0	0	3	5
Nitzchia nitzcloidea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Oestrupia zanardiniana	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0
Pleurosigma spp.	5	4	0	5	0	1	5	1	0	8	0	7	0	0	0
Pseudonitzchia spp.	7	0	0	7	0	6	5	4	0	0	8	0	0	8	5
Rhabdonema punctatum	0	0	0	0	4	5	5	2	0	9	0	5	0	0	0
Skeletonema sp.	0	0	0	0	0	7	8	1	0	0	7	0	0	0	7
Synedra spp.	0	0	0	0	5	0	0	0	7	0	2	5	0	2	0
Surirella fastuosa	0	0	0	0	8	2	5	5	0	0	0	0	0	0	3
Sub Total	36	26	10	26	39	63	60	59	15	33	37	27	52	38	58
Prorocentrium sp.	0	2	3	1	2	6	8	5	0	0	0	0	10	0	2
Total	36	28	13	27	41	69	68	64	15	33	37	27	62	38	60
Total Number of Speies	8	6	4	7	9	14	14	15	4	6	7	7	11	8	13

	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75
Coscinodiscus centralis	0	3	3	0	0	0	0	0	0	0	0	3	8	0	1
Coscinodiscus minor	0	2	0	0	0	6	5	7	3	0	2	2	0	0	2
Cosmioneis sp.	5	5	5	0	3	0	0	0	0	0	0	0	0	0	0
Cyclotella spp	2	6	0	0	2	7	6	0	4	8	4	2	0	9	0
Craticula sp.	0	3	7	2	0	0	0	0	8	5	5	0	0	6	0
Diatoma sp.	6	5	0	0	0	8	4	0	3	2	7	0	3	8	4
Diploneis vagabuda	0	0	9	4	0	0	0	4	0	0	0	0	0	2	0

	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75
Entomoneis sp.	0	4	0	0	5	0	0	0	0	0	0	0	0	8	0
Grammatophora marina	0	2	6	0	1	1	3	3	0	0	0	0	1	0	6
Gyrosigma balticum	4	0	0	6	0	0	0	0	3	2	7	0	0	0	0
Gyrosigma peisonis	0	8	0	0	0	0	0	5	0	0	0	0	0	0	2
Mastogloia exilis	6	5	4	0	0	0	0	8	0	0	0	0	0	4	0
Mastogloia paradoxa	0	2	0	7	0	0	0	5	3	0	3	2	7	7	0
Navicula spp.	0	0	7	0	0	8	0	2	1	5	0	0	0	0	0
Nitzchia spectabilis	5	0	0	6	0	9	0	0	8	2	0	6	5	4	0
Nitzchia nitzcloidea	0	0	0	0	0	5	0	0	0	0	1	0	0	0	5
Oestrupia zanardiniana	0	0	3	0	0	1	0	3	9	8	0	0	6	1	0
Pleurosigma spp.	0	8	0	0	0	0	0	0	0	0	0	0	7	0	0
Pseudonitzchia spp.	0	7	0	0	0	0	0	0	0	0	4	0	6	0	0
Rhabdonema punctatum	3	5	5	9	8	0	5	0	0	0	0	0	4	3	4
Skeletonema sp.	0	8	0	8	5	0	2	4	4	0	6	2	0	0	0
Synedra spp.	0	6	2	3	2	0	0	0	2	0	0	0	0	1	0
Surirella fastuosa	0	5	0	0	0	0	3	0	6	0	8	1	0	4	5
Sub Total	31	84	51	45	26	45	28	41	54	32	47	18	47	57	29
Prorocentrium sp.	0	8	0	0	5	0	0	6	0	7	0	8	0	0	4
Total	31	92	51	45	31	45	28	47	54	39	47	26	47	57	33
Total Number of Speies	7	18	10	8	8	8	7	10	12	8	10	8	9	11	9

Appendix 2.4: Detailed results for Phytoplankton in the JK Field during Contd.

	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90
Coscinodiscus centralis	0	4	0	0	0	0	2	3	0	5	6	7	0	2	5
Coscinodiscus minor	0	0	5	4	3	3	0	3	3	4	6	0	0	0	0
Cosmioneis sp.	3	0	0	0	0	0	0	8	0	7	0	0	6	4	8
Cyclotella spp	0	3	1	0	2	0	0	9	0	0	0	4	8	0	0
Craticula sp.	0	0	0	2	0	2	8	0	0	4	4	0	5	5	0
Diatoma sp.	0	5	0	0	0	0	0	0	7	0	0	0	0	0	6
Diploneis vagabuda	0	0	4	3	6	1	8	0	0	0	0	1	0	0	0
Entomoneis sp.	4	0	9	0	0	0	3	5	5	6	5	0	0	0	0
Grammatophora marina	0	0	6	0	5	4	0	0	3	0	0	0	0	7	1
Gyrosigma balticum	0	0	8	5	5	0	0	0	2	0	0	4	0	0	0
Gyrosigma peisonis	0	0	2	0	5	0	0	0	6	0	0	0	9	8	0
Mastogloia exilis	0	3	0	7	8	0	0	3	0	6	7	6	0	0	2
Mastogloia paradoxa	2	0	0	0	0	0	0	0	8	0	0	0	8	0	0
Navicula spp.	0	0	0	7	0	9	0	0	0	0	0	7	0	0	0
Nitzchia spectabilis	0	0	4	0	4	5	8	2	0	0	0	0	0	6	3
Nitzchia nitzcloidea	0	0	4	4	0	0	3	0	0	0	3	0	5	0	0
Oestrupia zanardiniana	0	0	9	0	0	0	0	0	0	5	0	4	0	0	0
Pleurosigma spp.	4	0	2	0	0	0	0	0	8	0	0	8	3	0	5
Pseudonitzchia spp.	4	0	3	0	0	0	0	7	5	2	7	0	0	0	6
Rhabdonema punctatum	0	0	4	0	0	0	8	0	8	0	0	0	0	2	0
Skeletonema sp.	0	0	0	0	4	0	0	0	0	0	1	0	3	0	4
Synedra spp.	3	3	4	0	0	0	0	7	0	0	2	0	2	0	7
Surirella fastuosa	0	6	0	5	0	6	0	0	0	0	0	0	0	5	0
Sub Total	20	24	65	37	42	30	40	47	55	39	41	41	49	39	47
Prorocentrium sp.	2	0	6	0	4	0	4	2	4	0	5	4	1	0	0
Total	22	24	71	37	46	30	44	49	59	39	46	45	50	39	47
Total Number of Speies	7	6	15	8	10	7	8	10	11	8	10	9	10	8	10

Appendix 2.4: Detailed results for Phytoplankton in the JK Field during Contd.

	91	92	93	94	95	96
Coscinodiscus centralis	7	7	0	0	0	2
Coscinodiscus minor	0	0	4	0	4	0
Cosmioneis sp.	4	8	0	1	0	0
Cyclotella spp	0	0	6	0	5	0
Craticula sp.	0	0	0	0	0	3
Diatoma sp.	2	6	7	1	0	0
Diploneis vagabuda	0	0	0	0	7	0
Entomoneis sp.	0	9	0	3	0	3
Grammatophora marina	0	0	9	0	5	5
Gyrosigma balticum	5	0	0	5	0	0
Gyrosigma peisonis	0	7	3	0	0	0
Mastogloia exilis	0	0	0	9	6	0
Mastogloia paradoxa	7	0	0	0	4	0
Navicula spp.	0	0	1	6	0	0
Nitzchia spectabilis	0	6	0	0	0	5
Nitzchia nitzcloidea	8	0	0	0	0	3
Oestrupia zanardiniana	0	0	7	4	7	2
Pleurosigma spp.	0	0	9	0	3	0
Pseudonitzchia spp.	0	4	0	1	8	0
Rhabdonema punctatum	6	0	0	0	0	2
Skeletonema sp.	0	5	2	0	5	0
Synedra spp.	3	0	0	3	0	0
Surirella fastuosa	0	0	0	5	2	0
Sub Total	42	52	48	38	56	25
Prorocentrium sp.	2	0	0	0	0	0
Total	44	52	48	38	56	25
Total Number of Speies	9	8	9	9	11	8

Appendix 2.4: Detailed results for Phytoplankton in the JK Field during Contd.

	CT1	CT2	CT3	TOTAL
Bacillariophyceae				
Ditylum sp.	0	0	0	0
Entomoneis sp.	0	3	2	5
Fragilariopsis sp.	6	4	1	11
Leptocylindrus sp.	0	0	0	0
Licmophora sp.	0	0	0	0
Melosira sp.	0	0	0	0
Navicula sp	0	0	0	0
Nitzschia sp	0	0	0	0
Chaetoceros spp	0	0	0	0
Coscinodiscus sp.	8	6	7	21
Rhizosolenia sp.	0	0	0	0
Skeletonema sp.	0	0	0	0
Stephanopyxis sp.	0	0	0	0
Pleurosigma sp	0	5	2	7
Pseudo-nitzschia sp.	0	0	0	0
Thalassionema sp.	0	0	0	0
Thalassiosira sp.	0	0	0	0
Sub Total	14	18	12	44
Dinophyceae				
Alexandrium sp.	3	0	4	7
Dinophysis sp.	5	0	3	8
Ceratium furca	8	0	0	8
Ceratium fusus	0	1	0	1
Tripos longipes	0	0	0	0
Noctiluca scintillans	3	2	1	6
Protoperidinium sp.	0	0	0	0
Scrippsiella sp.	5	0	7	12

	CT1	CT2	CT3	TOTAL
Sub Total	24	3	15	42
Fragilariophyceae				
Asterionella sp.	0	9	8	17
Haptophyceae				
Coccolithophora sp	0	3	2	5
Dictyochophyceae				
Dictyocha sp.	0	0	0	0
TOTAL	38	33	37	108
Total Number of Species	6	7	10	23

Appendix 2.5: Detailed results for Zooplankton in the JK Field during

		Sampling stations																		
Genus	Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Hexanauplia	Aegisthus mucronatus	6	0	5	0	4	0	5	0	6	7	1	0	0	3	7	0	6	0	0	4
	Acartia tonsa	0	3	8	0	1	0	4	0	0	0	0	2	3	0	5	6	7	0	2	5
	Acrocalanus longicornis	2	2	0	0	2	0	0	5	4	3	3	0	3	3	4	6	0	0	0	0
	Elminius modestus	7	0	3	8	4	0	5	0	0	0	0	0	0	7	0	0	0	0	0	6
	Bestiolina Arabica	0	0	0	2	0	0	0	4	3	6	1	8	0	0	0	0	1	0	0	0
	Semibalanus balanoides (larvae)	5	0	0	6	0	0	0	0	2	0	2	8	0	0	4	4	0	5	5	0
	Canthocalanus pauper	0	0	1	0	6	0	0	6	0	5	4	0	0	3	0	0	0	0	7	1

		Sampling stations																		
Genus	Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
	Calanopia elliptica	7	0	0	0	0	0	0	8	5	5	0	0	0	2	0	0	4	0	0	0
	Euchaeta concinna	0	0	0	0	2	0	0	2	0	5	0	0	0	6	0	0	0	9	8	0
	Ambunguipes spp.	3	2	7	9	0	2	0	0	0	0	0	0	0	8	0	0	0	8	0	0
	Oithona nana	0	6	5	4	0	0	0	4	0	4	5	8	2	0	0	0	0	0	6	3
	Oithona setigera	1	0	0	0	5	0	0	4	4	0	0	3	0	0	0	3	0	5	0	0
	Sub Total	31	13	29	29	24	2	14	33	24	35	16	29	8	32	20	19	18	27	28	19
Oligotrichea	Strobilidium sp	0	0	4	0	5	0	0	0	0	0	3	0	5	0	0	6	0	4	0	0
	Tintinnus sp	0	0	6	1	0	0	3	9	0	0	0	0	0	0	5	0	4	0	0	0
	Tintinnopsis sp.	5	2	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	4	0
	Sub Total	5	2	10	1	5	0	3	9	0	0	3	0	5	0	9	6	4	4	4	0
Malacostraca	Euphausia recurva	0	0	0	4	0	0	3	0	7	8	0	0	3	0	6	7	6	0	0	2
	Alpheus sp. (nauplius)	0	0	0	0	0	0	0	0	7	0	9	0	0	0	0	0	7	0	0	0
	Sub Total	0	0	0	4	0	0	3	0	14	8	9	0	3	0	6	7	13	0	0	2
Polychaeta	Tomopteris spp.	0	0	7	0	0	4	0	2	0	0	0	0	0	8	0	0	8	3	0	5
Stenolaemata	Actinopora sp.	0	0	0	0	0	3	0	0	0	0	0	0	8	0	7	0	0	6	4	8
Branchiopoda	Daphnia sp.	4	2	0	9	0	0	3	1	0	2	0	0	9	0	0	0	4	8	0	0
Calanoida	Calanoides spp.	0	0	0	8	0	4	0	9	0	0	0	3	5	5	6	5	0	0	0	0
	Total	40	17	46	51	29	13	23	54	38	45	28	32	38	45	48	37	47	48	36	34
	Total Number of Species	9	6	9	9	8	4	6	11	8	9	8	6	8	9	9	7	9	8	7	8

Appendix 2.5: Detailed results for Zooplankton in the JK Field during Contd.

Genus	Species	Sampling locations																			
		21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
Hexanauplia	Aegisthus mucronatus	0	0	2	3	2	0	4	3	0	2	0	1	4	6	0	8	9	0	3	0
	Acartia tonsa	7	7	0	0	0	2	0	0	0	5	3	5	0	6	7	4	5	0	0	0
	Acrocalanus longicornis	0	0	4	0	4	0	0	2	0	8	2	3	2	0	1	3	8	0	0	0
	Elminius modestus	2	6	7	1	0	3	3	4	6	0	5	5	0	0	0	2	0	3	5	6
	Bestiolina Arabica	0	0	0	0	7	8	0	7	0	0	0	8	0	0	4	0	0	0	0	0
	Semibalanus balanoides (larvae)	0	0	0	0	0	3	0	5	6	0	3	8	0	4	0	0	5	0	0	0
	Canthocalanus pauper	0	0	9	0	5	0	0	4	4	6	2	0	0	0	0	0	6	8	0	0
	Calanopia elliptica	5	0	0	5	0	0	7	0	0	4	0	8	0	0	0	0	4	0	5	4
	Euchaeta concinna	0	7	3	0	0	5	5	6	5	9	8	4	0	0	0	0	2	0	3	0
	Ambunguipes spp.	7	0	0	0	4	0	2	0	0	0	0	0	0	0	0	0	3	0	5	0
	Oithona nana	0	6	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0	3	5	5
	Oithona setigera	8	0	0	0	0	3	0	6	7	0	0	0	0	0	0	0	0	0	2	0
	Sub Total	29	26	25	9	22	24	27	37	28	34	23	42	6	16	12	17	42	14	28	15
Oligotrichea	Strobilidium sp	0	0	0	0	3	0	0	0	0	0	5	3	0	0	0	0	0	0	0	0
	Tintinnus sp	0	0	7	4	7	0	8	0	0	0	0	0	0	0	0	0	0	6	0	0

Genus	Species	Sampling locations																			
		21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
	Tintinnopsis sp.	0	4	0	0	0	0	0	0	0	3	1	8	0	0	5	0	3	0	6	0
	Sub Total	0	4	7	4	10	0	8	0	0	3	6	11	0	0	5	0	3	6	6	0
Malacostraca	Euphausia recurva	0	0	0	9	6	0	3	0	0	0	0	0	0	0	0	0	8	2	0	6
	Alpheus sp. (nauplius)	0	0	1	6	0	5	0	0	6	0	0	0	0	0	0	0	0	0	8	0
	Sub Total	0	0	1	15	6	5	3	0	6	0	0	0	0	0	0	0	8	2	8	6
Polychaeta	Tomopteris spp.	0	0	9	0	3	2	0	0	0	1	5	1	0	8	0	7	0	0	0	0
Stenolaemata	Actinopora sp.	4	8	0	1	0	0	0	8	4	2	5	3	0	0	0	0	0	6	0	5
Branchiopoda	Daphnia sp.	0	0	6	0	5	0	3	7	0	3	0	0	5	3	6	1	3	0	4	2
Calanoida	Calanoides spp.	0	9	0	3	0	9	0	0	0	5	4	2	1	3	2	0	8	0	6	0
	Total	33	47	48	32	46	40	41	52	38	48	43	59	12	30	25	25	64	28	52	28
	Total Number of Species	6	7	9	9	10	9	9	10	7	11	11	14	5	6	6	6	12	6	10	6

Appendix 2.5: Detailed results for Zooplankton in the JK Field during Contd.

		41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
Hexanauplia	Aegisthus mucronatus	4	0	0	0	4	4	4	3	0	0	0	0	0	0	0	0	0	0	0	6
	Acartia tonsa	3	3	0	0	0	0	0	0	0	4	10	2	8	0	0	0	3	7	3	0
	Acrocalanus longicornis	2	0	0	0	6	5	7	3	0	0	3	5	0	0	0	0	4	6	4	0
	Elminius modestus	5	0	0	0	8	4	0	3	2	0	6	2	2	0	0	0	0	0	4	4
	Bestiolina Arabica	0	9	4	0	0	0	4	0	0	0	0	0	0	2	5	3	8	0	0	0

		41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
	Semibalanus balanoides (larvae)	3	7	2	0	0	0	0	8	5	0	4	4	6	7	8	0	0	4	2	4
	Canthocalanus pauper	2	6	0	1	1	3	3	0	0	5	4	4	6	7	8	0	0	0	0	0
	Calanopia elliptica	0	0	6	0	0	0	0	3	2	0	0	0	0	0	0	0	0	0	0	0
	Euchaeta concinna	8	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	4	4
	Ambunguipes spp.	2	0	7	0	0	0	5	3	0	3	12	10	0	0	0	0	0	0	0	0
	Oithona nana	0	0	6	0	0	0	0	8	2	0	0	0	0	0	0	0	0	0	0	0
	Oithona setigera	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Sub Total	29	25	25	1	24	16	28	31	11	12	39	27	22	16	21	3	15	17	17	18
Oligotrichea	Strobilidium sp	5	0	0	3	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Tintinnus sp	0	3	0	0	1	0	3	9	8	5	0	6	0	4	0	0	5	0	2	0
	Tintinnopsis sp.	1	0	2	0	5	0	0	0	0	7	0	0	2	0	3	5	4	0	0	0
	Sub Total	6	3	2	3	10	0	3	9	8	12	0	6	2	4	3	5	9	0	2	0
Malacostraca	Euphausia recurva	5	4	0	0	0	0	8	0	0	0	0	4	4	6	7	8	0	0	0	0
	Alpheus sp. (nauplius)	0	7	0	0	8	0	2	1	5	5	2	1	0	0	0	0	0	0	0	0
	Sub Total	5	11	0	0	8	0	10	1	5	5	2	5	4	6	7	8	0	0	0	0
Polychaeta	Tomopteris spp.	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	4	1	0
Stenolaemata	Actinopora sp.	5	5	0	3	0	0	0	0	0	4	4	2	4	4	6	7	8	0	0	0
Branchiopoda	Daphnia sp.	6	0	0	2	7	6	0	0	0	0	3	0	6	0	0	7	5	3	0	0
Calanoida	Calanoides spp.	4	0	0	5	0	0	0	0	0	3	0	0	0	0	0	0	0	4	4	6
	Total	63	44	27	14	49	22	41	41	24	36	48	40	38	30	37	30	43	28	24	24
	Total Number of Species	15	8	6	5	10	5	9	9	6	8	9	10	8	6	6	5	8	7	8	5

Appendix 2.5: Detailed results for Zooplankton in the JK Field during Contd.

		61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80
Hexanauplia	Aegisthus mucronatus	9	10	4	8	0	0	0	0	0	3	2	5	3	5	0	6	5	7	5	2
	Acartia tonsa	4	8	0	6	5	2	2	0	4	0	1	8	2	7	4	7	8	2	0	0
	Acrocalanus longicornis	0	0	0	0	0	6	1	3	4	6	6	2	5	5	5	8	0	0	0	0
	Elminius modestus	6	7	8	0	0	0	6	5	2	2	0	3	0	9	4	5	7	9	0	8
	Bestiolina Arabica	0	0	0	4	4	6	7	8	0	0	0	5	4	0	6	0	0	0	5	3
	Semibalanus balanoides (larvae)	4	6	7	0	0	0	0	0	0	0	5	6	5	3	2	2	6	0	0	5
	Canthocalanus pauper	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	3	0
	Calanopia elliptica	0	0	0	0	0	0	0	0	0	0	0	0	8	3	0	0	0	0	4	5
	Euchaeta concinna	3	8	0	0	0	0	0	0	0	0	0	3	2	0	4	6	8	0	0	0
	Ambunguipes spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	6	4	3	1	0	4	7
	Oithona nana	0	0	0	0	0	0	0	0	0	0	0	0	5	5	0	0	0	0	4	3
	Oithona setigera	0	4	0	0	0	0	0	0	0	0	0	3	1	8	0	0	0	0	6	8
	Sub Total	26	43	19	18	9	14	16	16	10	11	14	35	40	51	29	37	35	18	31	41
Oligotrichea	Strobilidium sp	0	0	0	4	2	4	4	6	0	0	0	8	5	7	0	0	0	0	3	0
	Tintinnus sp	0	0	0	6	0	0	5	4	0	5	0	7	5	0	0	0	0	0	0	0
	Tintinnopsis sp.	0	2	0	5	0	0	7	0	0	7	0	8	7	0	0	0	0	0	0	0
	Sub Total	0	2	0	15	2	4	16	10	0	12	0	23	17	7	0	0	0	0	3	0
Malacostraca	Euphausia recurva	0	0	0	0	0	0	0	0	0	0	0	0	0	9	5	8	0	0	0	0
	Alpheus sp. (nauplius)	0	0	0	0	0	0	0	0	0	0	0	0	9	8	6	2	3	0	5	8
	Sub Total	0	0	0	0	0	0	0	0	0	0	0	0	9	17	11	10	3	0	5	8
Polychaeta	Tomopteris spp.	0	0	0	0	0	0	0	0	0	0	4	6	5	0	0	0	0	0	0	0
Stenolaemata	Actinopora sp.	0	0	0	4	6	8	4	0	0	0	8	0	0	8	4	3	0	5	7	0
Branchiopoda	Daphnia sp.	0	0	3	6	0	9	0	0	0	3	0	5	3	5	6	2	2	0	0	8
Calanoida	Calanoides spp.	7	8	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	8	8

		61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80
	Total	33	53	22	43	17	35	36	26	10	26	26	69	76	88	50	52	40	23	54	65
	Total Number of Species	6	8	4	7	4	6	8	5	3	6	6	13	17	14	11	11	8	4	11	11

Appendix 2.5: Detailed results for Zooplankton in the JK Field during Contd.

		81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	**C1**	**C2**	**C3**
Hexanauplia	Aegisthus mucronatus	0	5	8	0	0	5	0	3	2	1	0	3	0	4	0	0	4	8	0
	Acartia tonsa	3	0	6	0	2	0	5	0	4	6	0	0	9	8	0	0	0	6	5
	Acrocalanus longicornis	0	8	3	8	0	0	0	0	0	5	4	8	0	0	0	0	0	0	0
	Elminius modestus	3	8	6	9	6	0	0	0	0	0	3	8	6	7	5	0	8	0	0
	Bestiolina Arabica	0	0	0	0	0	0	0	0	0	0	5	0	3	2	1	0	0	4	4
	Semibalanus balanoides (larvae)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	0	0
	Canthocalanus pauper	0	0	0	0	0	3	2	5	0	7	4	0	0	0	0	3	0	0	0
	Calanopia elliptica	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Euchaeta concinna	0	0	0	0	0	0	0	0	0	0	3	6	4	1	3	0	0	0	0
	Ambunguipes spp.	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	6	0
	Oithona nana	7	0	0	0	3	8	6	6	9	0	0	0	0	0	0	0	0	0	0
	Oithona setigera	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Sub Total	25	21	23	17	11	16	13	14	15	19	19	25	22	22	9	3	29	24	9

		81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	**C1**	**C2**	**C3**
Oligotrichea	Strobilidium sp	0	0	0	0	0	0	0	0	0	0	5	0	3	2	1	0	0	4	2
	Tintinnus sp	0	0	0	0	0	0	0	0	0	0	0	3	2	1	0	3	0	6	0
	Tintinnopsis sp.	0	0	0	0	0	0	0	0	0	0	0	0	5	2	6	0	0	5	0
	Sub Total	0	0	0	0	0	0	0	0	0	0	5	3	10	5	7	3	0	15	2
Malacostraca	Euphausia recurva	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Alpheus sp. (nauplius)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Sub Total	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Polychaeta	Tomopteris spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Stenolaemata	Actinopora sp.	1	0	0	0	4	0	4	0	2	0	1	0	1	0	2	3	0	4	6
Branchiopoda	Daphnia sp.	5	0	9	3	6	5	0	7	4	7	0	0	0	0	5	0	0	0	0
Calanoida	Calanoides spp.	0	0	0	0	0	0	0	0	0	0	0	5	0	3	2	1	0	0	0
	Total	31	21	32	20	21	21	17	21	21	26	25	33	33	30	25	10	29	43	17
	Total Number of Species	7	3	5	3	5	3	4	4	5	5	7	6	8	9	8	4	4	7	4

Appendix 2.6: Detailed results for Macrobenthos in the JK Field during

		SW1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Gastropoda	Conus marmoreus	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	1	0	1	0
	Neptunea antiqua	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Margarites helicinus	0	1	0	0	0	0	0	0	0	0	0	1	0	1	0	1	0	0	0	0	0	0	0	0	0
	Vokesimurex elenensis	1	3	1	0	0	0	0	0	0	0	0	0	2	0	1	2	3	0	1	0	0	1	6	1	0
	Stigmaulax elenae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	1	0	0	0	0	1	1	1	0
	Ptychosyrinx sp	0	0	1	0	0	0	0	1	0	1	0	0	0	2	0	0	0	0	0	0	0	0	1	0	0
	Bursa sp	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	1	0	0
	Neptunea ventricosa	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
	Ophiodermella inermis	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Bela atlantidea	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
	Glyphoturris rugirima	0	0	0	1	0	0	0	0	3	0	1	0	1	0	0	1	0	0	0	0	0	0	2	1	1
	Heterocithara sp.	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
	Bathytoma neocalendonic	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0
	Oenopota uschakovi	0	0	0	0	0	0	0	2	1	3	0	0	0	0	0	1	0	0	0	0	0	0	2	0	0
	Genota mitriformis	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Aporhais spp	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	2	1	1	0

		SW1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
	Colpospira sp	2	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	3	0	1	0	2	1	1
	Cryplogemma corneus	0	0	1	1	0	0	0	0	1	0	1	0	0	0	0	1	2	0	0	0	0	0	0	0	0
	Eucithara amabilis	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	1	0	0
	Sub Total	5	4	5	3	0	1	4	3	9	9	4	1	3	3	3	12	6	0	5	0	1	6	18	7	2
Bivalvia	Aequipecten opercularis	7	13	4	13	1	4	7	0	7	5	5	11	3	6	2	3	0	2	12	5	3	4	3	7	8
	Chlamy opercularis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2	0	0	3	0	0	1	0	0
	Mercenaria mercenaria	5	29	19	12	19	3	34	32	14	38	7	48	5	26	0	22	5	14	0	12	0	10	0	7	0
	Cerastoderma glaucum	0	2	9	4	0	0	10	5	0	0	16	0	7	0	0	14	0	12	0	4	0	6	18	0	4
	Mya arenaria	26	29	9	3	4	6	20	0	8	0	8	0	6	0	10	12	14	10	27	8	12	1	8	9	15
	Sub Total	38	73	41	32	24	13	71	37	29	43	36	59	21	32	13	51	21	38	39	32	15	21	30	23	27
	Total	43	77	46	35	24	14	75	40	38	52	40	60	24	35	16	63	27	38	44	32	16	27	48	30	29
	Total Number of Species	6	5	9	7	3	4	5	4	10	7	8	3	6	4	3	15	6	4	5	5	3	9	13	10	5

Appendix 2.6: Detailed results for Macrobenthos in the JK Field during Contd.

		SW 26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50
Gastropoda	Conus marmoreus	0	1	0	0	0	0	1	4	0	0	0	0	0	0	0	0	0	0	2	0	1	0	0	0	0
	Neptunea antiqua	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
	Margarites helicinus	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0

		SW 26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50
	Vokesimurex elenensis	0	1	4	1	0	1	1	1	1	1	2	0	2	0	0	1	0	0	2	1	3	0	0	0	0
	Stigmaulax elenae	0	1	0	0	0	0	3	0	0	1	1	0	0	0	1	2	0	0	1	0	0	0	0	0	0
	Ptychosyrinx sp	0	0	0	0	3	0	1	3	0	0	0	0	0	0	0	0	0	0	0	8	0	0	0	0	0
	Bursa sp	0	0	0	0	0	0	1	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Neptunea ventricosa	0	0	0	0	0	0	11	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
	Ophiodermella inermis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
	Bela atlantidea	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Glyphoturris rugirima	0	0	2	0	0	0	4	0	2	0	2	0	0	0	0	3	0	0	0	0	0	0	0	0	0
	Heterocithara sp.	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0
	Bathytoma neocalendonic	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
	Oenopota uschakovi	0	0	0	3	0	1	1	2	4	0	2	1	0	0	0	0	0	0	5	0	1	0	0	0	0
	Genota mitriformis	0	0	0	0	2	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0
	Aporhais spp	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
	Colpospira sp	0	0	0	0	0	3	1	0	1	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0
	Cryplogemma corneus	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	1	0	0
	Eucithara amabilis	0	0	0	0	0	0	1	1	0	1	0	0	11	0	0	0	0	0	0	0	0	0	0	0	0
	Sub Total	3	3	6	4	5	9	28	14	9	3	9	5	14	4	1	6	0	2	10	9	5	0	5	0	0

		SW 26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50
Bivalvia	Aequipecten opercularis	6	1	0	0	0	4	5	11	9	4	1	4	8	1	3	4	0	13	4	6	0	0	8	0	0
	Chlamy opercularis	0	0	0	0	0	1	2	0	0	0	5	0	0	0	0	0	0	0	1	0	0	0	0	0	0
	Mercenaria mercenaria	18	0	0	3	4	0	18	0	0	0	8	0	17	49	52	12	0	0	0	32	11	0	14	0	0
	Cerastoderma glaucum	11	3	0	6	3	0	9	0	7	0	8	0	0	0	3	17	0	5	3	0	13	0	10	0	0
	Mya arenaria	2	23	0	0	3	10	8	0	11	14	0	27	0	0	0	0	0	2	16	0	2	0	6	0	0
	Sub Total	37	27	0	9	10	15	42	11	27	18	22	31	25	50	58	33	0	20	24	38	26	0	38	0	0
	Total	40	30	6	13	15	24	70	25	36	21	31	36	39	54	59	39	0	22	34	47	31	0	43	0	0
	Total Number of Species	4	6	2	4	5	6	17	7	8	5	10	5	15	4	4	6	0	5	8	4	6	0	8	0	0

Appendix 2.6: Detailed results for Macrobenthos in the JK Field during Contd.

		S1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Gastropoda	Conus marmoreus	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	1	4	0	0	0	1	1	0
	Turritella cingulifera	0	0	0	1	0	0	2	1	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0
	Margarites helicinus	0	0	0	1	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0
	Vokesimurex elenensis	0	4	0	2	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	2	2	0	3
	Genota mitriformis	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
	Stigmaulax elenae	0	2	0	0	0	0	3	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	2	0
	Ptychosyrinx sp	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
	Neptunea ventricosa	0	1	0	2	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

		S1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
	Ptychosyrinx sp	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	1	0	0	1	0	0	0
	Eucithara dubiosa	0	1	0	0	0	0	2	26	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
	Glyphoturris rugirima	0	0	0	1	0	0	2	0	1	0	0	0	2	0	0	0	0	3	0	0	0	0	2	0
	Heterocithora sp.	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0
	Bathytoma neocaledonica	0	0	0	2	2	1	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
	Oenopota uschakovi	0	3	0	3	0	0	0	1	0	0	4	1	0	0	0	0	0	0	0	0	0	2	0	0
	Genota mitriformis	1	0	0	1	0	0	2	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0
	Aporhais spp	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0
	Turritella incrasata	0	0	0	0	3	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
	Gemmula rarimaculata	2	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Cryplogemma corneus	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	1	0	0	0	0	0	0	0
	Comarmondia gracilis	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	1	0	0	0	0	0	0
	Eucithara amabilis	0	0	1	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
	Sub Total	3	11	1	13	19	8	13	29	5	1	11	3	4	5	1	0	4	9	3	0	3	11	5	4
Bivalvia	Aequipecten opercularis	7	0	8	7	10	9	12	13	2	13	10	0	4	4	2	2	19	12	10	5	13	0	4	5
	Chlamy opercularis	1	6	0	5	0	0	0	0	0	2	0	9	0	0	0	0	0	1	0	0	1	0	0	0
	Mya arenaria	7	11	26	11	12	37	6	42	0	8	12	21	10	7	12	18	14	11	16	14	11	13	12	14
	Mercenaria mercenaria	12	6	11	18	26	3	10	32	0	19	17	7	13	9	9	3	29	7	2	19	10	24	8	6
	Cerastoderma glaucum	3	0	14	14	4	4	10	7	0	13	0	0	5	11	7	5	0	11	0	2	0	0	4	0

		S1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
	Sub Total	30	23	59	55	52	53	38	94	2	55	39	37	32	31	30	28	62	42	28	40	35	37	28	25
	Total	33	34	60	68	71	61	51	123	7	56	50	40	36	36	31	28	66	51	31	40	38	48	33	29
	Total Number of species	7	8	5	13	10	9	11	8	6	6	7	6	7	7	5	4	7	9	6	4	6	9	7	5

Appendix 2.6: Detailed results for Macrobenthos in the JK Field during Contd.

		ASW1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Gastropoda	Margarites helicinus	0	0	0	0	0	2	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Vokesimurex elenensis	1	1	3	1	0	3	0	0	0	0	2	0	0	1	2	1	2	1	0	1	1	0	1	0	0
	Stigmaulax elenae	0	0	2	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
	Ptychosyrinx sp	2	0	0	0	0	2	0	0	0	0	3	2	0	1	0	0	0	1	3	0	0	3	0	0	0
	Bursa sp	1	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0
	Neptunea ventricosa	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Ptychosyrinx sp	0	0	6	1	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	1	0	0	0	3	0
	Ophiodermella inermis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Glyphoturris rugirima	0	2	0	0	0	0	0	0	0	2	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
	Heterocithora sp.	0	0	0	0	0	1	2	0	0	0	0	1	0	0	0	3	0	0	0	0	0	0	0	0	0
	Bathytoma neocaledonica	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
	Oenopota uschakovi	0	1	0	0	1	0	0	0	2	0	1	0	0	0	0	0	0	1	3	0	0	0	0	0	0

		ASW1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
	Genota mitriformis	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Aporhais spp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Amalda vernedev	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Mya arenaria	11	11	0	3	12	0	7	0	0	11	0	5	0	0	0	6	0	0	0	5	0	0	0	6	0
	Turritella incrasata	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	2	2	0
	Eucithara amabilis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	2	0	0
	Sub Total	17	15	11	8	13	8	11	0	4	18	6	8	1	2	3	11	3	3	7	9	2	3	5	11	0
BiValvia	Aequipecten opercularis	0	6	7	0	2	4	1	1	5	7	9	2	15	5	0	5	11	6	6	6	3	8	7	6	0
	Mercenaria mercenaria	21	3	30	2	0	30	15	19	14	3	33	11	18	42	31	26	13	24	21	9	7	15	26	0	0
	Cerastoderma glaucum	6	0	0	7	0	6	11	0	0	0	0	4	0	0	0	4	1	0	2	2	0	0	0	6	0
	Sub Total	27	9	37	9	2	40	27	20	19	10	42	17	33	47	31	35	25	30	29	17	10	23	33	12	0
	Total	44	24	48	17	15	48	38	20	23	28	48	25	34	49	34	46	28	33	36	26	12	26	38	23	0
	Total Number of Species	8	6	5	8	3	8	7	2	4	6	5	6	3	4	3	7	5	5	6	8	4	3	6	6	0