1.5.3 Royal Decrees

1.5.3.1 Royal Decree on Protection of Protected Areas (1993)

Article 1

The Secretariat of Sate for Environment is responsible for supervising the planning and development of the National Protected Areas System, incorporating the protection of terrestrial, wetland and coastal environments. The system is divided into the following categories of reserves:

- National Parks: Natural and scenic areas of significance for their scientific, educational and recreational values
- Wildlife Sanctuaries: Natural areas where nationally significant species of flora and fauna, natural communities, or physical features require specific intervention for their perpetuation
- Protected Landscapes: Nationally significant natural and semi-natural landscapes which must be maintained to provide opportunities for recreation and tourism
- Multiple-use Management Areas: The areas which provide for the sustainable use of water resources, timber, wildlife, fish, pasture and recreation with the conservation of nature primarily oriented to support these economic activities

1.5.4 Sub-Decrees

1.5.4.1 Sub-Decree on Environmental Impact Assessment Process (1999)

Article 1

The main objective of this Sub-Decree is to require that every private or public project or activity be assessed by the MoEin order to evaluate the potential environmental impacts that may be created prior to project submission for a Royal Government of Cambodia decision.

Institutional Responsibilities

Article 3

The MoE hasresponsibilities to:

a) Scrutinize and review EIA reports in collaboration with other concerned ministries;

b) Follow up, monitor and take appropriate measures to verify that a Project Owner follows the approved Environmental Management Plan (EMP) and any MoE requirements specified in the EIA Report during project construction, operation and abandonment.

Article 4:

Institutions and ministries responsible for a project have the right to examine and approve any project(s) as listed in the Annex to this Sub-Decree. (The Annex lists oil and gas projects).

Determination of Requirement for EIA

Article8

A Project Owner is required to apply to the MoE for review of the EIA report and pre-feasibility report (if applicable) when a project has the potential to significantly impact natural resources, ecosystems, human health or public welfare.

Note:For the Project, a full EIA will be submitted and no feasibility report is developed.

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Note:For the Project, a full EIA will be submitted and no feasibility report is developed.

Article11

A Project Owner must pay all service fees associated with the review and monitoring of the project. These service fees shall be approved by the Ministry of Economy and Finance following the proposal of the MoE. The fee is incorporated into the national budget.

Article13

An Environmental Application Form (EAF) must be completed by a Project Owner and must be submitted to the MoE when a project is subject to ministerial approval.

Procedures of EIA Process for Proposed Projects

Article14

A Project Owner must prepare and submit to MoE an EIA report and forward a copy to the Ministry/Institution approving the project.

Article 15

The MoE will review EIA report, as described in article 14 and will provide findings and recommendations back to the Project Owner and to the Project Approval Ministry/Institution within 30 working-days, commencing from the date of registration of their IEIA report and pre-feasibility study report.

Article16

When a full EIA report is required, the Project Owner must submit the EIA Report (along with their application for project investment approval) to the MoE and the Project Approval Ministry/Institution.

Article17

The MoE reviews the EIA reportand provides its findings and recommendations on the content of the report to the Project Owner and to the Project Approval Ministry/Institution within 30 work-days, commencing from the date of the receipt of the EIA report and pre-feasibility report.

Article18

If the MoE fails to provide its findings and recommendations as described in Article 15 and 17, the Project Approval Ministry/Institution assumes that the EIA report has complied with the criteria of this Sub-Decree, and is therefore approved.

Article19

The Project Owner must carry out all of the procedures as described in Charter 3 and 4 of this Sub-Decree.

Article20

The Project Owner must acknowledge the findings and recommendations of the EIA report when approved by the MoE and before the project can proceed to implementation.

Conditions for Approving Projects

Article27

The Project Approval Ministry/Institution may provide guidelines to the Project Owner on the Environmental Management Plan described in the EIA report approved by the MoE.

Article28

The MoE co-operates with other line ministries/institutions to halt existing/ongoing project activities when the Project Owner fails to implement the EMP set out in the approved EIA report.

1.5.4.2 Sub-Decree on Air Pollution and Noise Disturbance (2000)

The monitoring of air emissions and noise from mobile sources is the responsibility of MoE with the cooperation of concerned ministries and institutions. The monitoring procedure is determined by a joint declaration among the ministries concerned.

During an environmental inspection or activity aimed at controlling pollution sources, MoE inspectors may take and analyze samples.

The owner or person responsible for the emissions may ask to have a sample tested at another public or private laboratorythat is formally recognized (to carry out the same analytical method as used in the MoE laboratory).

The owner or person responsible for air emissions and noise shall:

- Procure and install equipment toprevent or control emissions, noise and vibration in order to meet required standards;
- Install equipment to measure the amount of pollutants emitted by the sources and maintain the results in its record, with quarterly reporting of the results; and
- Appoint an environmental expert to be responsible for managing environmental affairs and preparing environmental protection plans for the facility (Note: MoE may provide training on request).

When there is a complaint or report relating to air emissions, noise or vibration which has the potential to impact human health or public property, the MoE, in collaboration with concerned ministries, is entitled to inspectthe source of emissionsand take samples for testing.

Ambient air quality standards areshown in **Table 1-1**.

Table 1-1: Ambient Air Quality Standard

No.	Parameter	1 Hour Average Mg/M^3	8 Hours Average Mg/M^3	24 Hours Average Mg/M^3	1 Year Average Mg/M^3
1	Carbon Monoxide (CO)	40	20		
2	Nitrogen dioxide (NO_2)	0.3		0.10	
3	Sulfur dioxide (SO_2)	0.5		0.30	0.10
4	Ozone (O_3)	0.2			
5	Lead (Pb)			0.005	
6	Total Suspended Particulates (TSP)			0.33	0.10

1.5.4.3 Sub-Decree on Solid Waste Management (1999)

Household Waste Management

Article 4

The MoEhas establishedmanagement guidelines on the collection, transport, storage and, disposal of household waste, and on waste recycling, reduction, re-use and dumping in order to manage household waste in a safe way and to monitor waste handling activities.

Article 7

The disposal of waste in public sites or anywhere that is not allowed by the authorities is prohibited.

Article 8

Investment in construction of landfill facilities, incinerators, waste storage sites or recycling plants for household waste is subject to prior approval by the MoE.

Hazardous Waste Management

Article 15

Storage, transportation and disposal of hazardous waste shall be undertaken separately from the household waste (to be stipulated by the MoE). Disposal of hazardous waste into a public site, public drainage systems, public water area, rural area or forest area is prohibited.

Article 17

Transportation or the construction of storage place or landfill for hazardous waste from factories and manufacturing sites shall be subject to a permit from the MoE.

Article 18

The owner of hazardous waste is responsible for its temporary storage, transport, and disposal using proper techniques and in a safe manner, and must prepare quarterly waste reports and submit them to the MoE. The waste report must include:

- Type and amount of the waste;
- Temporary storage method and site;
- Transport method; and
- Treatment or disposal method and site.

Article 19

Investment in the treatment or incineration of hazardous waste shall have prior approval from the MoE.

Monitoring and Inspection of Hazardous Waste Management

Article 22

Monitoring of packing, storage, transport, recycling, incinerating, treatment and disposal of the hazardous waste is the responsibility of the MoE.

Article 23

The MoE shall take samples of the hazardous waste at every point enumerated in Article 22.

Article 24

The samples of the hazardous waste which were taken during the monitoring or inspection shall be analyzed in the Laboratory of the MoE.

The owner or person responsible for the site stipulated in Article 23 can request to test his/her waste sample at other public or private laboratories which are recognized formally and those laboratories must use the same testing method as used in the laboratory of the MoE.

The owner or person responsible for the point or site stipulated in Article 23 shall pay analysis fee of his/her own waste sample following the list of testing cost determined by the MoE and the Ministry of Economy and Finance.

These incomes shall be incorporated into the national budget for allocating the Environmental Endowment Fund.

Article 25

In the case of illegal disposal or dumping of the hazardous waste without a permit from the competent institution, the MoE in collaboration with concerned ministries shall conduct inspection.

Article 26

In case of complaint or report that there is storage or disposal of the hazardous waste which causes danger to animal or human health or public property, or contamination of the environment, theMoE shall make urgent inspection and inform concerned ministries and local authority.

1.5.4.4 Sub-Decree on Water Pollution Control (1999)

Water Pollution Monitoring in Public Water Areas

The MoE shall regularly monitor water quality at public water areas in order to provide good water quality and to takemeasuresto maintain it and to prevent and reduce water pollution. The MoEis also required to manage data from water quality testing and assess the status of the quality of public water areas throughout the Kingdom of Cambodia.

Ambient water quality standards have been set for public water areas to protectbiodiversity resources and public health. Public water has been defined as three main sources such as river, lake and reservoir, and coastal waters. Coastal waters are waters that are less than 12 nm from shore, i.e. not Block A's offshore waters.

The standards for wastewater discharges to public water areas are shown in**Table 1-4**.

Table 1-2:Water Quality Standards in Public Water Areas for Bio-Diversity Conservation (including Coastal Water)

No.	Parameter	Unit	Standard Value
1	pH	mg/l	7.0 – 8.3
2	COD	mg/l	2 – 8
4	Dissolved Oxygen	mg/l	2 - 7.5
5	Coliform	MPN/100ml	< 1000
5	Oil content	mg/l	0
6	Total Nitrogen	mg/l	0.2– 1.0
7	Total Phosphorus	mg/l	0.02 – 0.09

Table 1-3:Water Quality Standards in Public Water Areas for Public Health Protection

No.	Parameter	Unit	Standard Value
1	Carbon tetrachloride	µg/l	< 12
2	Hexachloro-benzene	µg/l	< 0.03
3	DDT	µg/l	< 10
4	Endrin	µg/l	< 0.01
5	Diedrin	µg/l	< 0.01
6	Aldrin	µg/l	< 0.005
7	Isodrin	µg/l	< 0.005
8	Perchloroethylene	µg/l	< 10
9	Hexachlorobutadiene	µg/l	< 0.1
10	Chloroform	µg/l	< 12
11	1,2 Trichloroethylene	µg/l	< 10
12	Trichloroethylene	µg/l	< 10
13	Trichlorobenzene	µg/l	< 0.4
14	Hexachloroethylene	µg/l	< 0.05

No.	Parameter	Unit	Standard Value
15	Benzene	µg/l	< 10
16	Tetrachloroethylene	µg/l	< 10
17	Cadmium	µg/l	< 1
18	Total mercury	µg/l	< 0.5
19	Organic mercury	µg/l	0
20	Lead	µg/l	< 10
21	Chromium, VI	µg/l	< 50
22	Arsenic	µg/l	< 10
23	Selenium	µg/l	< 10
24	Polychlorobiohenyl	µg/l	0
25	Cyanide	µg/l	< 0.005

Table 1-4:Effluent Standards for Discharges of Wastewater to Public Water Areas or Sewer

No	Parameters	Unit	Allowable limits for pollutant substance discharging to	
			Protected public water area	Public water area and sewer
1	Temperature	^{0}C	<45	< 45
2	pH		6 – 9	5 - 9
3	BOD5 (5 days at 200 C)	mg/l	< 30	< 80
4	COD	mg/l	< 50	< 100
5	Total Suspended Solids	mg/l	<60	<120
6	Total Dissolved Solids	mg/l	< 1000	< 2000
7	Grease and Oil	mg/l	< 5.0	< 15
8	Detergents	mg/l	< 5.0	< 15
9	Phenols	mg/l	< 0.1	< 1.2
10	Nitrate (NO3)	mg/l	< 10	< 20
11	Chlorine (free)	mg/l	< 1.0	< 2.0
12	Chloride (ion)	mg/l	< 500	< 700
13	Sulfate (as SO4)	mg/l	< 300	< 500
14	Sulfide (as Sulfur)	mg/l	< 0.2	< 1.0
15	Phosphate (PO4)	mg/l	< 3.0	< 6.0
16	Cyanide (CN)	mg/l	< 0.2	< 1.5
17	Barium (Ba)	mg/l	< 4.0	< 7.0
18	Arsenic (As)	mg/l	< 0.10	< 1.0
19	Tin (Sn)	mg/l	< 2.0	< 8.0
20	Iron (Fe)	mg/l	< 1.0	< 20
21	Boron (B)	mg/l	< 1.0	< 5.0
22	Manganese (Mn)	mg/l	< 1.0	< 5.0
23	Cadmium (Cd)	mg/l	< 0.1	< 0.5
24	Chromium (Cr)+3	mg/l	< 0.2	< 1.0
25	Chromium (Cr)+6	mg/l	< 0.05	< 0.5
26	Copper (Cu)	mg/l	< 0.2	< 1.0
27	Lead (Pb)	mg/l	< 0.1	< 1.0
28	Mercury (Hg)	mg/l	< 0.002	< 0.05
29	Nickel (Ni)	mg/l	< 0.2	< 1.0
30	Selenium (Se)	mg/l	< 0.05	< 0.5
31	Silver (Ag)	mg/l	< 0.1	< 0.5
32	Zinc (Zn)	mg/l	< 1.0	< 3.0
33	Molybdenum (Mo)	mg/l	< 0.1	< 1.0
34	Ammonia (NH3)	mg/l	< 5.0	< 7.0
35	DO	mg/l	>2.0	>1.0
36	Polychlorinated Biphenyl	mg/l	<0.003	<0.003
37	Calcium	mg/l	<150	<200
38	Magnesium	mg/l	<150	<200
39	Carbon tetrachloride	mg/l	<3	<3
40	Hexachloro benzene	mg/l	<2	<2
41	DTT	mg/l	<1.3	<1.3
42	Endrin	mg/l	<0.01	<0.01

No	Parameters	Unit	Allowable limits for pollutant substance discharging to	
			Protected public water area	Public water area and sewer
43	Dieldrin	mg/l	<0.01	<0.01
44	Aldrin	mg/l	<0.01	<0.01
45	Isodrin	mg/l	<0.01	<0.01
46	Perchloro ethylene	mg/l	<2.5	<2.5
47	Hexachloro butadiene	mg/l	<3	<3
48	Chloroform	mg/l	<1	<1
49	1,2 Dichloro ethylene	mg/l	<2.5	<2.5
50	Trichloro ethylene	mg/l	<1	<1
51	Trichloro benzene	mg/l	<2	<2
52	Hexaxhloro cyclohexene	mg/l	<2	<2

1.5.5 International Conventions

1.5.5.1 UN Framework Convention on Climate Change and Kyoto Protocol

The UN Framework Convention on Climate Change (UNFCCC) (May 9, 1992)aims at reducing global warming and controlling its effects. The ultimate objective of the Convention is the "stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic (man-made) interference with the climate system. Such a level should be achieved within a time-frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner." Cambodia ratified the UNFCCC on 18 May 1995.

The Kyoto Protocol, binding on the signatories, is an international agreement to reduce greenhouse gas emissions worldwide. Cambodia ratified the Protocol for accession on August 22, 2002.

1.5.5.2 Montreal Protocol (1989)

The Montreal Protocol on Substances that Deplete the Ozone Layer is designed to reduce ozone-depleting substances (ODSs). Cambodia ratified the Protocol for accession on June 27, 2001 and the protocol amendments on May 1, 2007.

Signatory parties agree to:

- Control annual consumption and production of specified ODSs;
- Reduce consumption and production of specified ODSs by 50% from the July 1998 levels (countries with ODSs consumption under 0.3 kg/capita/yr are permitted an extra 10 years to phase out their use). Common ozone-depleting substances (ODSs) are: chlorofluorocarbons (CFCs), halon, carbon tetrachloride, methyl chloroform, and methyl bromide. They are used in the following applications:
    - Refrigeration compressors;
    - Vehicle and small- to medium-sized air conditioners;
    - Foams;
    - Spray cans of cosmetics, paints, drug etc;
    - Electronic microprocessors, computer hard disks (ODSs are used as anti-moisture and cleansing agents);
    - Pesticides, pharmaceutical products, industrial paints (ODSs are used as anti-moisture and cleansing agents); and
    - Fire extinguishers (halons are used).

1.5.5.3 Convention on Biological Diversity (1992)

The Convention on Biological Diversity is the first global agreement on the conservation and sustainable use of biological diversity.Cambodia signed the Convention for accession on February 9, 1995 and the Cartagena Protocol on Bio-safety on September 17, 2003.

The Convention has three main goals:

- Conservation of biodiversity;
- Sustainable use of the components of biodiversity; and
- Sharing the benefits arising from the commercial and other utilization of genetic resources in a fair and equitable way.

The Convention covers all ecosystems, species, and genetic resources. It is legally binding. Countries that join it are obliged to implement its provisions. The Convention deals with many issues, including impact assessment.

Cambodia as signatory to the Convention, shall as far as possible and appropriate:

- Regulate or manage biological resources important for the conservation of biological diversity whether within or outside protected areas with a view to ensure their conservation and sustainable use;
- Promote the protection of ecosystems, natural habitats and the maintenance of viable populations of species in natural surroundings;
- Endeavour to provide the conditions needed for compatibility between present uses and the conservation of biological diversity and the sustainable use of its components;
- Where a significant adverse effect on biological diversity has been determined regulate and manage the relevant processes and categories of activities;
- Encourage cooperation between government authorities and the private sector in developing methods for sustainable use of biological resources; and
- Promote public participation, particularly when it comes to assessing the environmental impacts of development projects that threaten biological diversity.

1.5.5.4 International Convention for Prevention of Pollution from Ships (MARPOL 73/78)

This convention came into force on October 2, 1983. Cambodia signed the Convention in 1996. The objectives of this convention are to establish measures to prevent marine pollution from vessels or platforms and to develop applicable mitigation measures.

There have been a total of six annexes to this convention, of which Cambodia has ratified five (as of December 1, 2011). The annexes Cambodia has ratified are:

- Annex I: Regulations for the Prevention of Pollution by Oil
- Annex II: Regulations for the Control of Pollution by Noxious Liquid Substances in Bulk
- Annex III: Prevention of Pollution by Harmful Substances Carried by Sea in Packaged Form
- Annex IV: Prevention of Pollution by Sewage from Ships
- Annex V: Prevention of Pollution by Garbage from Ships

Annex VI (Prevention of Air Pollution from Ships) has not been ratified by Cambodia.

1.5.5.5 United Nations Convention on the Law of the Sea (UNCLOS)

UNCLOS came into force on December 10, 1982. Cambodia signed the Convention on July 1, 1983. The objective of the Convention is the codification of the law of the sea and to contribute to the strengthening of peace, security, co-operation and friendly relations among all nations.

The following outlines the issuesrelevant to the Project:

- Protection and preservation of the marine environment including:
    - Measures to prevent, reduce and control pollution of the marine environment;
    - Pollution from activities in the Area; and
    - Pollution from vessels; and
    - Basic conditions of prospecting, exploration and exploitation.Cambodia has signed but not ratified the UNCLOS Convention.

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

The Basel Convention (1989) governs the movement and disposal of hazardous waste. The Convention was designed to address the uncontrolled movement and dumping of hazardous wastes, including incidents of illegal dumping in developing nations by companies from developed countries. Cambodia signed the Convention for accession on March 2, 2001. Its key objectives are to:

- Reducethe generation of hazardous wastes in terms of quantity and hazardousness;
- Dispose of them as close to the source of generation as possible; and
- Reduce the movement of hazardous wastes.

The following categories of waste are covered by the Convention:

- Clinical waste;
- Waste from the use of biocides and organic solvents;
- Waste oils, hydrocarbon mixtures, emulsions; and
- Residue from waste disposal operations, and waste containing heavy metals, phenols, etc.

2. PROJECT DESCRIPTION

2.1 Introduction

COPCL plans to develop the Apsara Field (Phase 1) in Block A and produce oil from up to 10 production platforms. Chevron's Block A concession is located approximately 157 km offshore Cambodia (**Figure 2-1**). Block A covers 4,709 square kilometres.

The project scope for the EIA is defined as follows[1]:

- **Up to ten platforms:**
    - One platform (Platform A) with 24 well slots and processing equipment with capacity of 25,000 barrels well liquid per day (BLPD) where crude oil, gas and water will be separated;
    - Up to nine wellhead platforms (B to J), with up to 24 well slots on each, linked to Platform A. One of nine wellhead platforms could be a second production platform (with processing equipment similar to platform A);
    - **Drilling of approximately 325 wells** including base wells, infill wells, horizontal wells, and dedicated injector wells. At the time of writing, the exact number is unknown as it will be determined by production levels.[2]
- **A permanently moored Floating Storage and Offloading (FSO) tanker:**
    - Between 640,000 bbls and 846,000 bbls capacity (pending upon vessel selection); with living quarters for 60 to 70 Personnel On Board (POB) ;
    - Crude oil will be stored on the FSO.
    - Offloading will take place on the FSO.
- **A crude oil pipeline linking the Phase 1a processing platform to the FSO**
    - Approximately 3.5 km long;
    - With a 8 inch diameter.
- **Flowlines linking the platforms B to J to platform A.**

This chapter presents the project description associated with the proposed Phase 1, which will be used for the evaluation and assessment of potential environmental and social impacts associated with the project.

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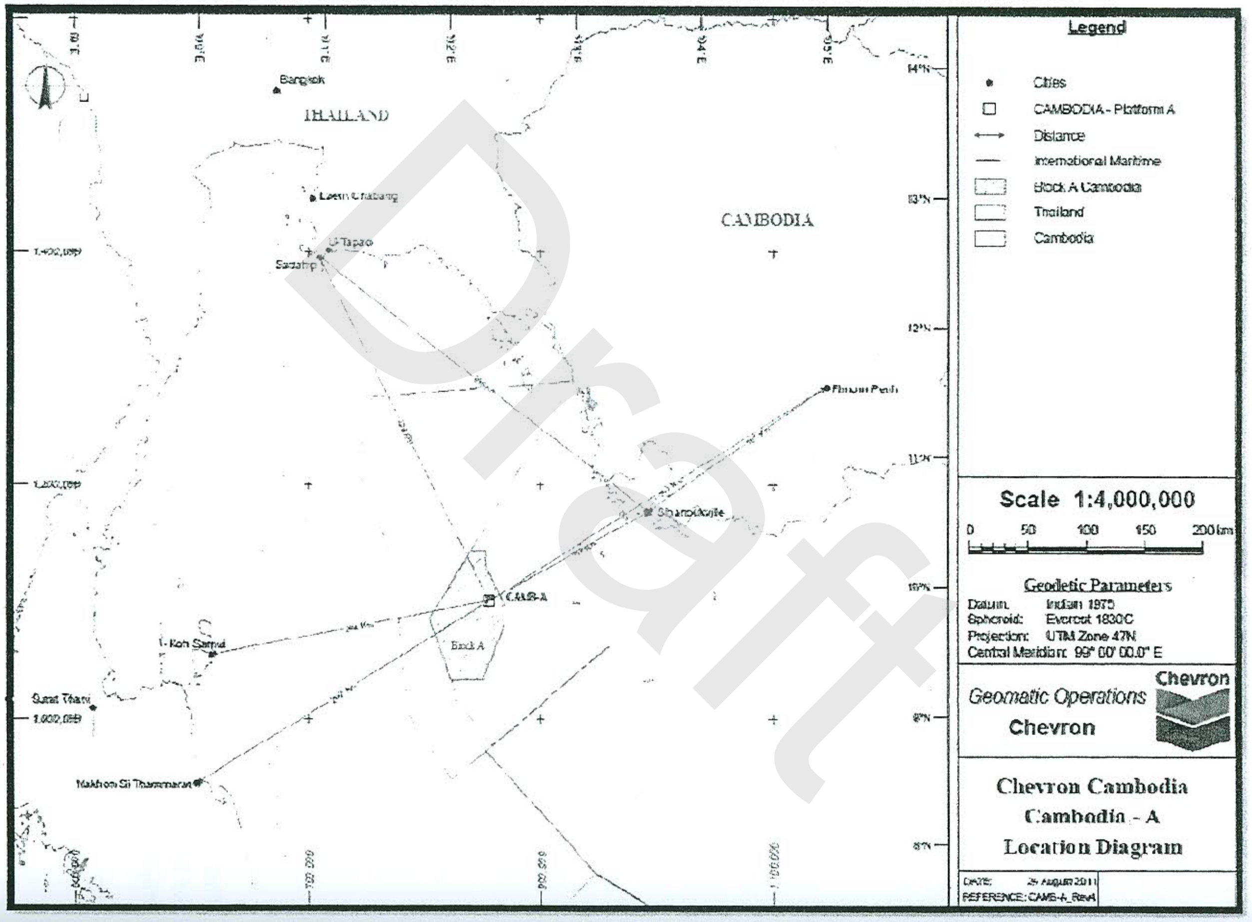
[1] The description is based on "EV" values which are "expected value" outcomes. The expected value represents the mean value of the distribution of outcomes that Chevron calculates for the project.

[2] Small variations in well numbers would not be significant in terms of impact assessment as the potential impacts have been considered from the maximum number of wells that would be drilled at one time (24 wells)

Figure 2-1: Location of Block A



2.2 Phased Approach

A phased development approach is adopted for the Apsara Project to gain knowledge about reservoir production and recovery efficiency in Block A. The individual oil accumulations in Block A are small in size and are spread over a large geographic area. Reservoir production performance in the Khmer Basin has yet to be proven. In addition, initial data indicates low primary recovery efficiency because the reservoir fluids contain oil with little associated gas and high amounts of wax. For these reasons, knowledge gained during the initial phase can be incorporated into later phases to increase oil recovery.

2.2.1 Initial Development – Phase 1a

The initial phase of the Apsara Field development starts with a single production platform (Apsara "A"). The Platform "A" is located in the North Apsara area.

The Phase 1a Apsara development consists of:

- **Installation of one platform with 24 well slots and associated processing equipment** with capacity of 25,000 BLPD where crude oil, gas and water will be separated;
    - Gas is consumed for fuel or gas lift to enhance well productivity; any excess gas will be flared;
    - Water is re-injected downhole into the dedicated water disposal wells.
- **Drilling of**:
    - Between 20 and 22 production wells;
    - Infill wells as sidetracks from installed wells to maintain production;
    - Two to four water injection wells.
- **Installation of a permanently moored Floating Storage and Offloading (FSO) tanker**:
    - Between 640,000 and 846,000 bbls capacity (pending upon final ship selection);
    - Living quarters for 60 to 70 Personnel On Board (POB) ;
    - Crude oil will be stored on the FSO;
    - Sales and offloading takes place on the FSO.
- **Installation of crude oil pipeline linking the Phase 1a processing platform to the FSO**
    - Approximately 3.5km long;
    - With an 8 inch diameter.

All field personnel accommodation will be located on the FSO with personnel travelling to the production Platform A by a field boat to support operations.

2.2.2 Future Potential Developments – Platforms B to J

The development of Block A beyond Phase 1a is dependent on the success of Phase 1a itself. Work on the future Phase 1b development and beyond would proceed subject to the following factors:

- successful execution of the Phase 1a single platform development;
- favourable and consistent production behaviour from the Phase 1a single platform; and

- successful results from further appraisal drilling .

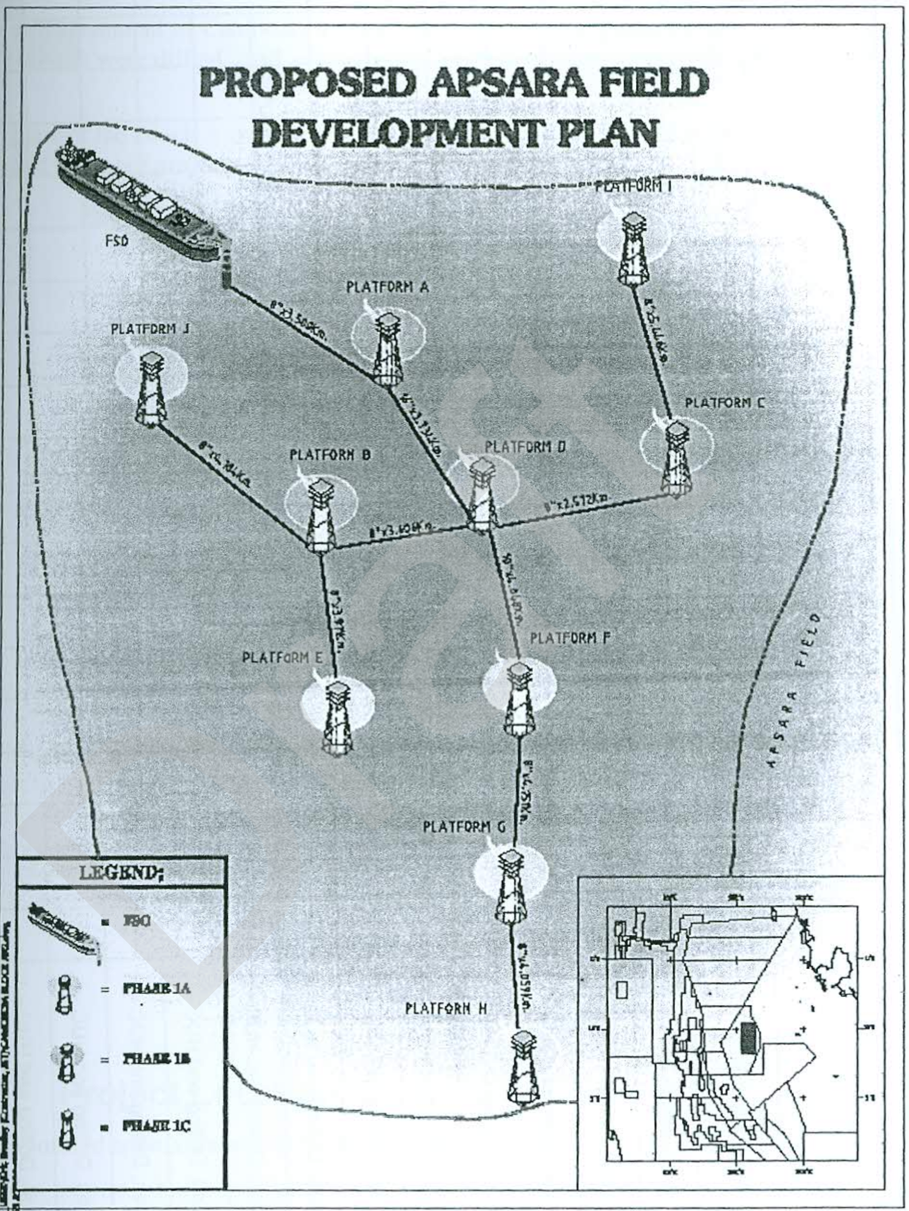
In addition to Phase 1a installations, Phase 1b and 1c will consist of[3]:

- Installation and operation of up to nine platforms (B to J) with up to 24 well slots on each platform;
- Platforms will be wellhead platforms with the probable exception of one, which could be a production platform with processing equipment as follows;
    - Capacity of 25,000 BLPD;
    - 3 phase separation (crude oil, gas and water);
    - Gas consumption for fuel or gas lift to enhance well productivity; any excess gas is reinjected or flared.
    - Water is re-injected downhole into the dedicated water disposal wells.
    - At the time of writing, the most likely platform to be a second potential CPP is Platform F.
- Drilling of approximately 283 wells, including additional production wells, infill wells to maintain production and dedicated injectors. At the time of writing, the exact number is unknown as it will be determined by production levels.
- Flowlines linking the wellhead platforms to the Apsara A Processing Platform;

The proposed Apsara Field Development is shown in **Figure 2-2.** The pipeline network may vary slightly depending on final platform locations and the need for a second processing platform.

[3] Subject to modification as the project develops.

Figure 2-2: Proposed Apsara Field Development



2.2.3 Schedule

The most probable schedule at the time of writing is shown in **Table 2-1**.

Table 2-1: Most Probable Installation and Drilling Schedule

Phase	Project Activities			Year 1		Year 2		Year 3		Year 4		Year 5		Year 6		Year 7		Year 8		Year 9	
		S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
1A	Platform A Installation	■																			
	Mooring and Pipeline installation	■																			
	Platform A Drilling and HUC		■																		
1B	Installation, Drilling and HUC - B								■												
	Installation, Drilling and HUC - C									■											
	Installation, Drilling and HUC - D										■										
1C	Installation, Drilling and HUC - E											■									
	Installation, Drilling and HUC - F												■								
	Installation, Drilling and HUC - G														■						
	Installation, Drilling and HUC - H															■					
	Installation, Drilling and HUC - I																		■		
	Installation, Drilling and HUC - J																			■	

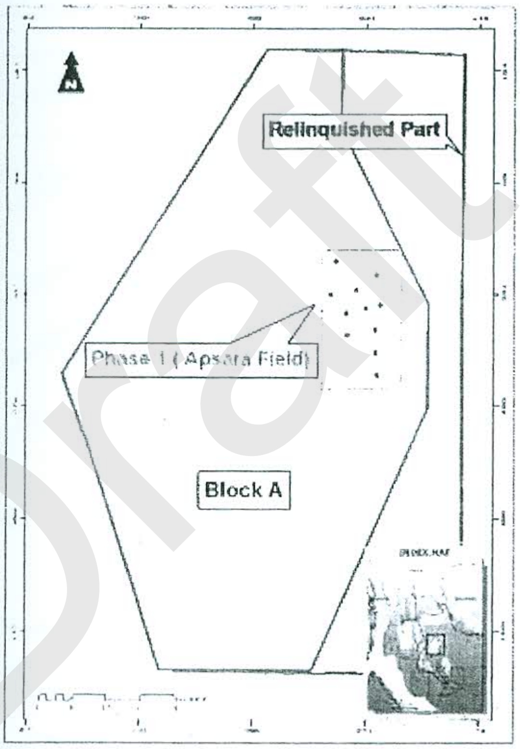
S = semester, HUC = Hook up and Commissioning
Preliminary and subject to change

2.3 History of Block A Exploration and Appraisal Activities

The Royal Government of Cambodia awarded COPCL an exploration license for Block A in 2002, a total of 18 wells were drilled , and subsequently COPCL declared a commercial discovery in August 2010.

In 2007, parts of the Block A exploration license were relinquished. The relinquished area and current Block A and proposed project areas are shown in **Figure 2-3.**

Figure 2-3: Block A Relinquished Area and Current Block A Area



2.4 Project Location

Block A is located approximately 157 km offshore Cambodia.

For onshore support, shorebases in Sihanoukville and in Thailand will be used during installation. During operations and drilling, the project team will use a shorebase located within or close to Sihanoukville Autonomous Port, Preah Sihanouk Province.

2.4.1 Coordinates of the Surface Facilities

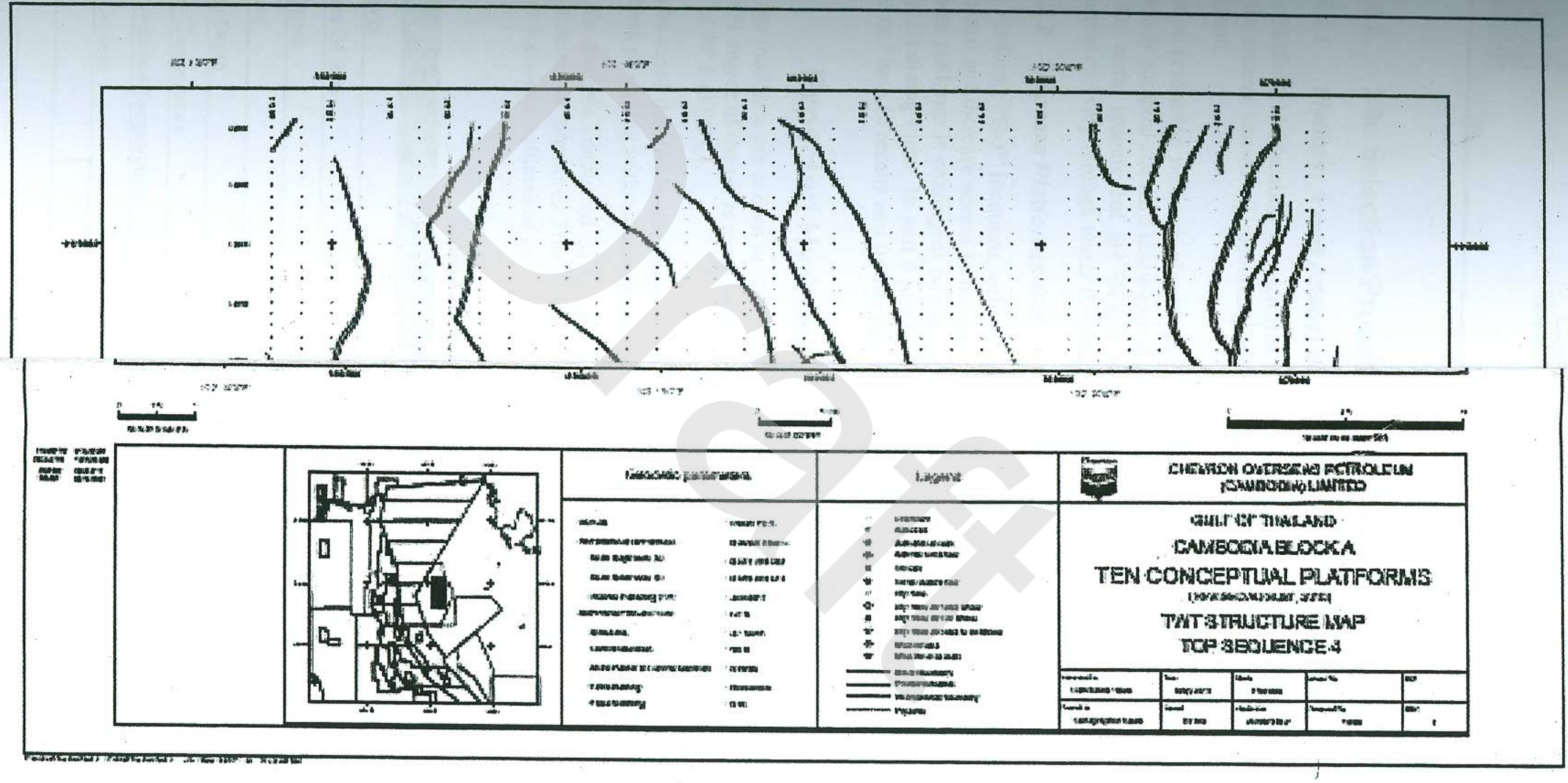
The preliminary coordinates of the FSO and the Phase 1 platforms are outlined in **Table 2-2** and are shown in **Figure 2-4**.

Table 2-2: Tentative Locations of Phase 1 Platforms and FSO

Phase 1 Platforms and FSO	Coordinates(Indain1975)	
	EASTING (mE)	NORTHING (mN)
Platform A	856150	1101280
Platform B	854510	1097000
Platform C	860501	1098506
Platform D	858000	1097906
Platform E	854800	1093100
Platform F	859629	1094200
Platform G	859725	1090050
Platform H	860000	1086000
Platform I	859750	1103900
Platform J	851878	1100253
FSO	852476	1106161

Note: these preliminary locations are tentative and subject to change during the detailed design phases.

Figure 2-4: Full Apsara Conceptual Development – Preliminary Platform Locations



2.4.2 Site Selection Process

2.4.2.1 Platform A and Associated Wells

The Platform "A" location was selected to provide access to potential well locations, increase access to the current known oil resources, and increase the potential resources accessed by each future platform.

Vertical production wells are placed approximately every 400 meters. This type of development is a generally accepted standard elsewhere in the GoT. Water injection and horizontal wells are not drilled on 400 meter spacing but are located to increase access to large oil accumulations and facilitate enhanced recovery through water flooding.

2.4.2.2 Apsara Platforms B-J

The Platforms "B-J" locations will be selected to provide access to all potential reservoirs (well locations) and increase access to the current known oil resources of the existing wells. Development of these platforms is contingent on the success of Phase 1a. It is planned to install three platforms (B, C and D) during Phase 1b and 6 platforms during Phase 1c. Final well locations will be determined based on Phase 1a results and further appraisal activities.

2.5 Expected Hydrocarbon Properties

Average fluid data are shown in **Table 2-3**. These properties are used for the design of the facilities. The API degree of the oil is expected to be 38. The oil has a wax content of about 27.2% and a pour point of 95° F (33.8°C).

It can be noted that fields elsewhere in the Gulf of Thailand with similar wax content and pour point have been producing without experiencing any significant wax related operational problems.

From the analysis conducted so far, the early stages of production will be characterized by a rapid drop in reservoir pressure. This leads to inefficient recovery and artificial lift will be required to produce economic volumes of oil.

Table 2-3: Measured Average Fluid Properties

Parameter	Average Value	Units
API Gravity	39.5 (36.1 to 43.9)	API degree
Basic Gas Oil Ratio	300 to 400	scf/bo
Wax Content	27.2 (23 to 29)	% wt.
Pour Point	95 (84 to 107.6)	^{0}F
Reservoir Depth	7,000 to 9,000	feet tvdss
Reservoir Temperature	280 to 306	^{0}F
Flowing Wellhead Temperature	108 to 141	^{0}F
Mercury Content	Approx 202	wt ppb
Arsenic	Approx 17	wt ppb
CO_2	5.15	% mol
H_2S	Not expected	% mol

Source: Process Basis of Design, COPCL, 2011.

2.6 Facilities

The fluid coming from the wells consists of a mixture of gas, crude oil and water. The three phases will be separated on Platform A.

- Oil leaving the production separator will be stabilized and transported into an export pipeline to the FSO;
- Produced water will be treated and disposed of downhole (reinjected) via booster and injection pumps;
- Gas will be used to fuel the platform and the rest of the gas will be flared during Phase 1a. During Phase 1b and 1c, the opportunity to reinject the gas will be evaluated. If reinjection of the gas is proved feasible, platform A will be modified to include a gas reinjection unit.

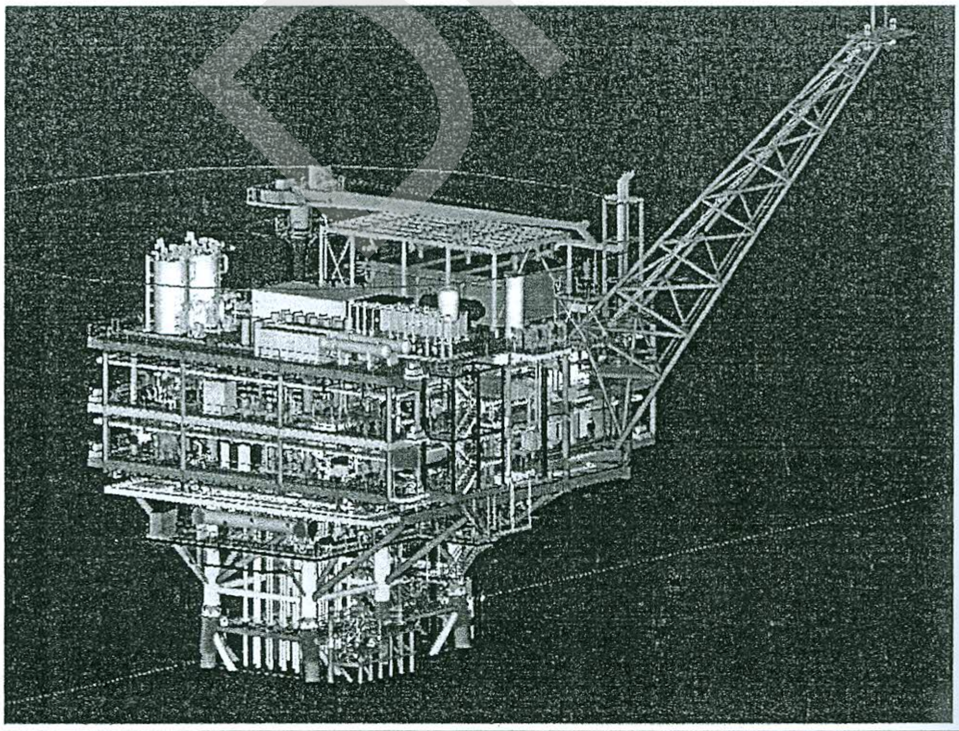
Technical Codes & Standards that apply to the project are available in **Appendix 2**.

2.6.1 Processing Platform A

2.6.1.1 Structure

The proposed processing platform is a four leg-jacket with central topside support. It accommodates 24 well slots. It will be set in approximately 233 feet of water (71m). Production facilities will be based as much as possible on existing platform designs which have proven to work for small oil field developments in the GoT. The platform will have four decks with a boat landing. The dimensions of the top deck area are 34.6m by 27.6m. A schematic representation of Platform A can be seen in **Figure 2-5**. Platform A has a design life of 15 years. It is designed to accommodate both Tender Assist Drilling rigs and Jack Up rigs.

Figure 2-5: Representation of Platform A.



2.6.1.2 Process Systems

Process systems can be seen on the Process Flow Diagram in **Figure 2-6**. The platform is designed to stabilise the crude oil and remove as much water as possible prior to sending it to the FSO. Produced water will be reinjected on the platform via a produced water reinjection system. Associated gas will be separated, with some being used as fuel gas and the remaining flared. Estimated flaring rates initially will be a maximum of 3.5 MMSCFD depending on the gas-to-oil ratio (GOR) of the reservoir fluids. The platform is also designed to accommodate periodic return of produced water from the FSO. The platform is designed to be upgraded to allow accepting production from future platforms in Phase 1b and 1c.

Capacity

Processing units are installed to handle 20,000 BOPD or 25,000 total barrels of liquid (oil and water) per day (BLPD). The gas flow capacity is 10 million standard cubic feet per day (MMCFD).

Initial oil production of Platform A is estimated to peak at 6,000 bopd with water peak rates at 5,000 bwpd. When Phase 1b is added, oil production is expected to peak at 16,000 bopd with associated water production of up to 17,000 bwpd. During phase 1c, oil production is estimated to peak at 26,000 bopd with associated water production of up to 27,000 bwpd.

Three Phase Production Separator

A three phase production separator separates gas, water and oil.

- The gas will be used as fuel gas, and fed to the gas lift compressor skid; excess gas will be flared on the platform;
- Dewatered crude goes to the LP Separator;
- The produced water is sent to the hydrocyclones for oil removal and to the degassing drum. It is then fed to the produced water booster pumps and produced water injection pumps for reinjection downhole.

The three-phase separator has a flooded weir design. Separated liquid is drained into the bottom of the vessel via a dipleg.

The production separator nominated design conditions are:

- Design pressure: 245 psig/ FV;
- Design temperature: 250 °F.

Provisional space is also provided for future installation of a multicyclone separator in case wax issues are encountered.

LP Separator

The LP separator provides three phase separation. The design is a similar style to the three phase - production separator:

- The design is flooded weir; a vane pack with dipleg will be installed;
- Flash gas will be separated from the fluid and is flared to the LP Flare system;
- Stabilized dewatered crude/emulsion is fed to the Crude export pumps. Any water in oil carry over will be managed on the FSO. Produced water will be sent to the production separator or to the hydrocyclones for oil removal. Two centrifugal, electrical driven pumps are used to transfer produced water from the LP separator to either the hydrocyclones or the production separator;

- The design conditions of the LP separator are the same design conditions of the production separator. The LP separator drains to the closed drains system.

Before Phase 1b, the feasibility to reinject gas from the LP and production separators will be studied. If this proves feasible, platform A will be modified to accommodate a gas injection system; it should be noted that the modifications may include the installation of a deck extension. Discharges and exhaust emission estimates for Phase 1b and Phase 1c assume these modifications.

Crude Export Pumps

While it is assumed that crude will free flow from the LP separator to the FSO when the pipeline is clean, after shutdowns, gels may form in the pipeline and high pressure fluid may be needed to flush the pipeline. Two electrical driven pumps will be installed to provide this high pressure fluid.

Test Separator

A test separator will be installed on the platform for well testing, wellbore blowdown operation and it can also be used for well clean up after drilling or well services. It consists of a 2-phase separator (liquid and gas) and is designed for full flow from one well. The vessel is cleaned out by opening a manway and collected into an outside drum.

The test separator nominated design conditions are:

- Design pressure: 1333 psig/ FV
- Design temperature: 250 °F

Pigging System

A permanent vertical pig launcher will be provided on the platform for pigging operations to the FSO.

Seawater System

The seawater system is designed to supply clean seawater for pipeline washdown, flusing and gel breaking purposes. It includes a seawater caisson and a removable seawater lift pump which operates inside the caisson.

Produced Water Treatment and Disposal System

Produced water leaving the production separator and the LP separator will be treated via a hydrocyclone. It then goes to a degassing drum for dissolved gas venting. From the degassing drum, the produced water will be disposed downhole via the produced water disposal wells using booster pumps and injection pumps.

The system includes the following equipment:

- Hydrocyclone (12,800 BWPD Capacity) expandible to 18,000 BWPD;
- Degassing drum – 7'-6" ID x 15' T/T – sized for 20,000 BWPD
- Booster pumps – 2 x 100% at 12,000 BWPD each
- Injection Pumps – 2 x 50% at 4,500 BWPD each (2 pumps installed initially with space for a third and fourth pumps to be potentially installed later giving a total of 18,000 BWPD)

The produced water treatment system is designed to be upgradable to provide the flexibility to handle full field requirements as future phases are developed.

Enough injection well capacity is available to inject two times the predicted water production plus additional capacity to handle additional water removed from the FSO.

In case of an upset at the FSO, production will be shut-in. Several activities will happen simultaneously in case injection capacity falls below the produced water volume as follows: a) Water will be stored on the FSO until either the injection problem is resolved or the FSO nears its storage capacity; b) remediation work will begin to restore injection capacity; c) production will be shut-in as needed to reduce the platform level water production and increase the volume of oil produced per barrel of produced water.

Gas Lift Manifold

The gas lift manifold provides gas lift for production wells (except for the wells which are equipped with Electrical Submersible Pumps (ESP)). It consists of one header with discharge slots. It connects to the gas lift supply lines. For platform A, 18 Gas lift supply lines are planned. The platforms that will be installed during Phase 1b and Phase 1c have the capability to connect 12 gas lift lines at any one time. These lines can be swapped to other wells as required.

The gas lift compressor is based on those used in GoT operations and provides gas lift capacity of 9.4 MMSCFD at 1,200 psi injection pressure. The compressor skid will be located on the mezzanine deck.

Electrical Submersible Pumps (ESP)

Electrical Submersible Pumps are used to recover production fluids . They are placed at the shoe of the intermediate casing. Four ESPs are planned for Platform A wells. They are part of the start up process of the platform, due to the lack of free gas from the reservoirs. The number of ESP for Phase 1b and 1c has not been determined yet and will be assessed after review of the operation of the ESP installed on Platform A.

Crude Oil Heater

A crude oil heater and associated heat exchangers will be installed for Phase 1b and Phase 1c on Platform A to heat incoming crude from other platforms to guarantee normal operating conditions on Platform A. Details on the heater will be defined at a later stage.

2.6.1.3 Platform A Utility Systems

Platform A has a number of utility systems as follows:

Gas Compression System

The gas compression system provides high pressure gas to the gas lift manifold. It consists of compressors driven by a gas engine driver. It includes a pre-cooler, suction scrubbers, compressors, collers and discharge scrubbers.

Fuel Gas System

The fuel gas system will filter the produced gas to provide clean, dry fuel gas for:

- Gas engines of power generators
- Degassing drum blanketing
- Flare ignition system
- Flare knock out drum purging
- Closed drain drum purging
- Gas engine of the gas lift compressor package

Flare System

A flare system is used for both High Pressure (HP) and Low Pressure (LP) flare systems.

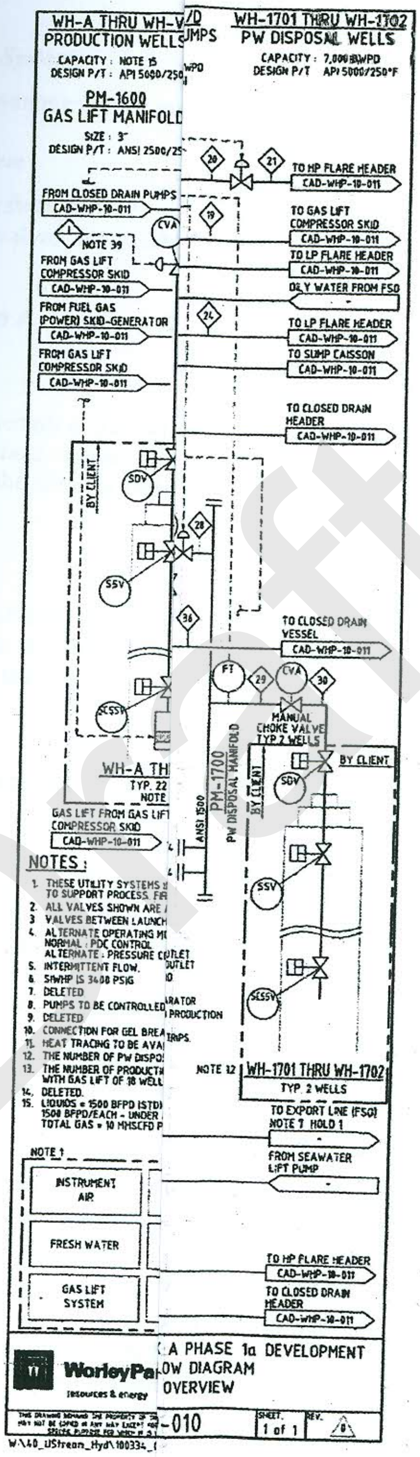
The HP flare system is designed to handle the maximum relief and blow down case and manual pipeline depressurization. The LP flare is designed to collect low pressure vent sources from test separator, LP separator, manual vents and degassing drum.

Closed and Open Drainage Systems

Conventional closed and open drain systems are provided, consisting of headers, sump tanks and sump pumps.

The closed drain system is designed to collect process liquids from manual and automated process drains which are routed to a closed drain vessel. It is located below the cellar deck. The closed drain pumps are electrical driven, positive displacement pumps. The closed drain pump discharge is fitted with a system to provide protection against over pressure and leaks.

An open drain tank is provided to collect and separate hydrocarbons from the rainwater and washdown water that falls on the deck. The open drain tank is designed for atmospheric operation. It collects the liquids from the decks drains, separates the oil and allows the water to be discharged to a sump caisson. To increase the separation of hydrocarbons the tank has an integral weir separation chamber and a hydrocarbon collection bucket. Hydrocarbon liquid is skimmed to the collection bucket that is installed with a level gauge system. When the level of the collection bucket reaches high, skimmed hydrocarbons are pumped off the bucket to the closed drain vessel by electrical driven open drain tank pumps. The water from the open drain tank is routed to the sump caisson located at the boat landing. The sump caisson is equipped with a system to transfer skimmed oil to the oil bucket inside the open drain tank. The tank is vented to the atmosphere to a safe area. Portable drip trays will be used during maintenance operations to reduce the potential for hydrocarbon spillage onto the deck.


WH-A THRU WH-V
PRODUCTION WELLS
CAPACITY : NOTE 15
DESIGN P/T : API 5000/250
PM-1600
GAS LIFT MANIFOLD
SIZE : 3"
DESIGN P/T : ANSI 2500/25
WH-1701 THRU WH-1702
PW DISPOSAL WELLS
CAPACITY : 7,000 BWPD
DESIGN P/T : API 5000/250°F
FROM CLOSED DRAIN PUMPS
CAD-WHP-10-011
NOTE 39
FROM GAS LIFT COMPRESSOR SKID
FROM FUEL GAS (POWER) SKID-GENERATOR
TO HP FLARE HEADER
TO GAS LIFT COMPRESSOR SKID
TO LP FLARE HEADER
TO SUMP CAISSON
TO CLOSED DRAIN HEADER
TO CLOSED DRAIN VESSEL
BY CLIENT
SDV
SSV
SCSSV
CVA
FT
MANUAL CHOKE VALVE TYP 2 WELLS
PM-1700
PW DISPOSAL MANIFOLD
ANSI 1500
GAS LIFT FROM GAS LIFT COMPRESSOR SKID
NOTES :
1. THESE UTILITY SYSTEMS TO SUPPORT PROCESS.
2. ALL VALVES SHOWN ARE
3. VALVES BETWEEN LAUNCH
4. ALTERNATE OPERATING NORMAL : PDC CONTROL ALTERNATE : PRESSURE
5. INTERMITTENT FLOW.
6. SIWHP IS 3400 PSIG
7. DELETED
8. PUMPS TO BE CONTROLLED
9. DELETED
10. CONNECTION FOR GEL BREA
11. HEAT TRACING TO BE AVAI
12. THE NUMBER OF PW DISPO
13. THE NUMBER OF PRODUCTI WITH GAS LIFT OF 18 WELL
14. DELETED.
15. LIQUIDS = 1500 BFPD (STD) 1500 BFPD/EACH - UNDER TOTAL GAS = 10 MMSCFD
NOTE 12
WH-1701 THRU WH-1702
TYP. 2 WELLS
TO EXPORT LINE (FSO) NOTE 7 HOLD 1
FROM SEAWATER LIFT PUMP
INSTRUMENT AIR
FRESH WATER
GAS LIFT SYSTEM
A PHASE 1a DEVELOPMENT
OW DIAGRAM
OVERVIEW
WorleyParsons
-010
1 of 1

Chemical Injection Systems

Chemical injection systems will be installed to inject production chemicals.

Instrument Air System

The instrument air system provides air to the wellhead control panel, the control valves, the shutdown valves, the actuated valves, the potable water pumps, the diesel pumps, compressors and distribution system.

2.6.1.4 Platform A Auxiliary Systems

Platform Crane

A crane with a boom length of 85 feet (25.9 m) will be installed. It is designed to reach the majority of the upper deck. The crane engine, diesel and hydraulic tanks are located on the crane upper works to allow easy access by the crane operator. An auxiliary line is provided for small lifts and for personnel transfers.

Utility Water System

Fresh water is provided from the utility water storage tank and distributed to safety showers and eye wash stations. The tank is refilled from a boat and a hose connection is provided at the boat landing. Water is gravity fed to the safety shower, hand basin and toilet.

Potable Water

There is no potable water system on the platform as it is not usually manned. Bottled water will be provided instead.

Diesel Fuel System

The diesel fuel system consists of a diesel storage tank, a diesel day tank and a diesel pump. The diesel is transferred from boat.

Fire Detection And Fighting Equipment

A number of pieces of safety equipment are installed. They include fire and gas detection, water mist fire fighting systems, Heating, Ventilating, and Air Conditioning (HVAC), safety showers, life rafts etc.

Power Generation System

Electric power is supplied by two gas engine generators and one dual fuel gas-diesel engine generator. This dual engine generator is used as an emergency generator.

Heat Tracing

Due to the potential for wax formation, heat tracing is required. It is used as necessary to maintain the fluid at an acceptable flowing temperature. Insulation will be provided.

Toilet

A toilet is provided on the platform.

Process Safety Systems

The platform has an Integrated Control and Safety System. There is a Process Control System, responsible for normal control and plant monitoring and a Safety Instrumented System which comprises of an Emergency shutdown system and a Fire and Gas system.

Communication

There is a dedicated radio link for communication between the FSO and the Platform. Portable marine radios, local area network, radio beacon and emergency communications are also provided.

2.6.1.5 Contingent Space for Phase 1b – 1c Platform A Transformation

Space on platform A will be provided for the following systems that may be installed during Phase 1b and Phase 1c:

- Future desanders
- Future riser
- Future pig receiver
- Future multicyclone separator.
- Future fire water pump and fire hoses.
- Future crude oil heating equipment

2.6.1.6 Exclusion Zone

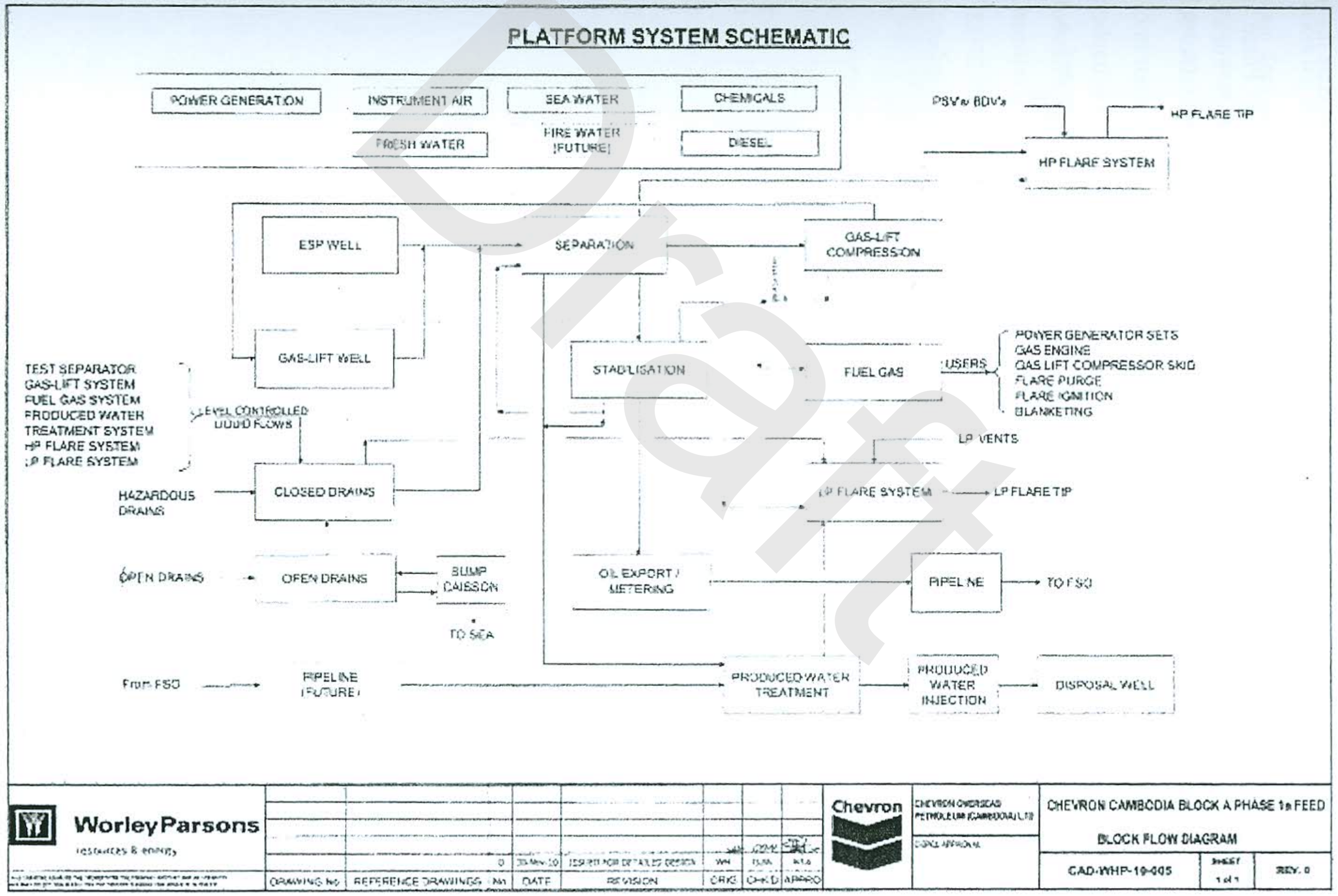
There will be a 500m exclusion zone around platform A. It will be indicated on nautical charts.

2.6.1.7 Manning Requirements

The platform is operated 24/7 with a minimum of two personnel. At the end of each shift the personnel will rotate back to the FSO, where they are accommodated.

The platform will be designed to reduce manning requirements with as much automation as practicable. The control room operator will be able to detect and handle process upsets from the control room. The ability to change set points, adjust levels, open and close valves and start/stop equipment will be provided via a Human Machine Interface (HMI) located in the Platform A control room. **Figure 2-7** represents the Platform A system schematic.

Figure 2-7: Platform A System Schematic



2.6.2 Phase 1b and 1c Wellhead Platforms B to J

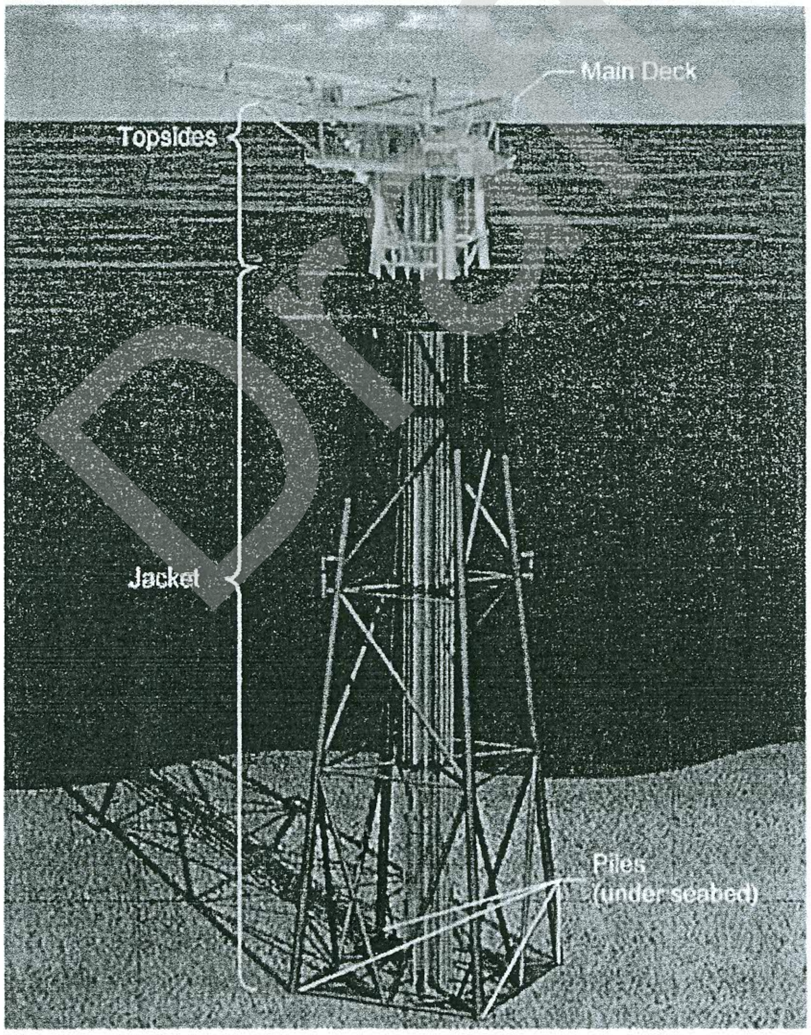
The future platforms in Phases 1b and 1c will be designed to accommodate the incoming production streams with risers and pig receiving facilities installed accordingly.

There is a possibility that one of nine potential wellhead platforms in Phase 1b and 1c will be a platform that is equipped with processing equipment similar to platform A. For a complete description of production processing platform please refer to Section 2.6.1. Details on wellhead platforms are provided below.

2.6.2.1 Structure

The platform structure is a four-leg-through-pile jacket substructure and a topside module. A schematic representation of a wellhead platform can be seen in **Figure 2-8**.

Figure 2-8: Well Head Platform B to J



Source: Chevron

The platform has three topside decks. Approximate platform dimensions are as follows:

- Pile diameter : 1.07m
- Jacket leg diameter : 1.21m
- Main deck area : 430 m2
- Cellar deck area : 510 m2
- Sub-cellar deck area : 175 m^2

Each platform supports 24 wells and includes:

- Production manifolds,
- Booster/ Gas lift compression units;
- Chemical injection;
- Pigging facilities;
- Flow-lines;
- Well test facility;
- Fuel gas system;
- Pipeline receivers and launchers;
- Remote control equipment;
- Closed and open drain sump tanks.

2.6.2.2 Utilities And Auxiliary Systems

Utility and auxiliary systems on each of the wellhead platforms include:

- Utility water;
- Drainage system;
- Instrument/utility gas system.

Utility Water

Utility water tanks and distribution system will be provided. The water will be used for safety shower and eye wash stations and also for washdown and for toilet flushing systems.

Potable/Drinking Water

Drinking water will be provided in the control room bottles, which will be transported to each platform by supply boats, as required.

Wash Water - Black Water

A toilet is provided on each WHP. Untreated sewage is discharged directly to the sea in accordance with MARPOL Annex V requirements. Water from the hand-basin (with water supply from the wash water tank) is also discharged directly to the sea without any treatment. Safety shower and eyewash stations are provided. A water tank (approximate capacity of 5,000 Liters) is installed on each WHP. Water is resupplied from workboats via a flexible line from the boat landing. This wash water is used for the hand basin adjacent to the toilet and any other wash water duties around the platform.

Drainage System

There are two drainage systems: an open drain system and a closed drain system.

The closed drain system collects process liquids from manual and automated process drains. These drains are routed to a Closed Drain Sump Tank. The closed Drain Sump Tank is located below the cellar deck to collect the process fluids. The tank is sized to contain liquids from the test separator during well unloading or well clean up operations. The tank is designed with a 50 psig design pressure. Flanged heads are used for to provide access to the tank during maintenance and to facilitate sand removal.

The Closed Drain Sump Pump is a gas driven, single acting with double heads, positive displacement pump. A flow switch is installed on the pump outlet to indicate when the pump is operating. The Closed Drain Sump Pump discharge system is fitted with a system to provide protection against over pressure events and leaks. The pump discharge line is also fitted with a PSV to prevent over pressure in the line due to blocked outlet.

An open drain system is provided to collect rainwater and runoff. An Open Drain Tank collects any hydrocarbons that may have spilled on to the deck. The Open Drains Tank, is designed for atmospheric operation (non pressurized), and is provided to collect the liquids from the deck drains, separate the oil and allow the water to be discharged overboard. The tank is installed below the cellar deck to allow all the deck drains to gravity discharge into it. Hydrocarbon collected in the oil bucket will be pumped to the Closed Drain Sump Tank with a gas driven diaphragm pump and the level is automatically controlled by a level controller. The tank is vented to atmosphere to a safe area with a flame arrestor fitted to the vent pipe.

Instrument/Utility Gas System

An instrument and utility gas system provides the motive gas for controlling instruments and for operating the diesel transfer pump, utility water pumps and chemical injection pumps.

The system consists of a scrubber vessel and filter coalescer to clean the gas prior to use.

2.6.2.3 *Manning*

For future Phases 1b and 1c, the manpower will be increased accordingly to enable efficient and safe operation of the additional facilities. The remote wellhead platforms will be semi automated, unmanned and designed in order that routine operations can be undertaken from the Platform A control room. Future wellhead platforms in Phases 1b and 1c, will be semi-automated platforms which will be operated via remote control in the Platform A control room. The potential second CPP will be operated with two personnel like Platform A.

2.6.2.4 *Exclusion Zone*

There will be a 500m exclusion zone around each wellhead platform. They will be indicated on nautical charts.

2.6.3 Production Chemicals

2.6.3.1 *Type, Functions And Approximate Consumption Of Chemicals*

Chemicals to be used on the platforms include:

- Corrosion inhibitor to reduce corrosion in vessels process piping and pipeline.
- Pour point depressant to reduce the probability of pipeline plugging.
- Defoaming/emulsion breaking chemicals to reduce incidence of foaming and aid separation in the Production and LP Separators.

Production chemicals used and estimated consumption during operations are listed in **Table 2-4**.

Consumption of pour point depressant may not be continuous. Volumes are preliminary and subject to change during detailed design.

Table 2-4: Production Chemicals

Function	Product Trade Name	Estimated Daily Usage per Production Platform (Gallons)	Estimated Daily Usage per Wellhead Platform (Gallons)
Corrosion inhibitor – Gas phase/ gas lift	EC1010A	2.6	2.6
Corrosion inhibitor- Liquid phase	EC1304A	27.3	27.3
Pour point dispersant	EC6509A	136.5	136.5
Forward demulsifier	PX0191	27.3	27.3
Reverse demulsifier	DVE4F004	10.9	Not required
Antifoam	EC9242S	8.2	Not required
Biocide	EC6388a	2	2
Biocide	EC6111E	2	2
Scale Inhibitor	EC6264A	8.2	Not required
Rig wash	DVE4K016	6.5	6.5
Oxygen Scavenger	EC6226A	126	Not required

2.6.3.2 *Storage of Chemicals*

The chemicals are stored in dedicated chemical storage tanks built into the platform on the Mezzanine deck. The tanks are filled periodically via 550 USG tote tanks.

2.7 FSO Vessel

The proposed FSO tanker is an Aframax type vessel. It has approximately between 640,000 bbls and 846,000 bbls storage capacity (depending on vessel's selection).

The FSO will be leased. It will be an existing vessel which will be modified as necesary to accommodate the project's specific requirements. At the time of the EIA development, the selection process is ongoing.

The primary purpose of the FSO is to store the produced crude until it is unloaded to tankers. The FSO will also accommodate the workforce.

2.7.1 Crew Accommodation and Transfer

The FSO will accommodate the workforce required for operating the field.

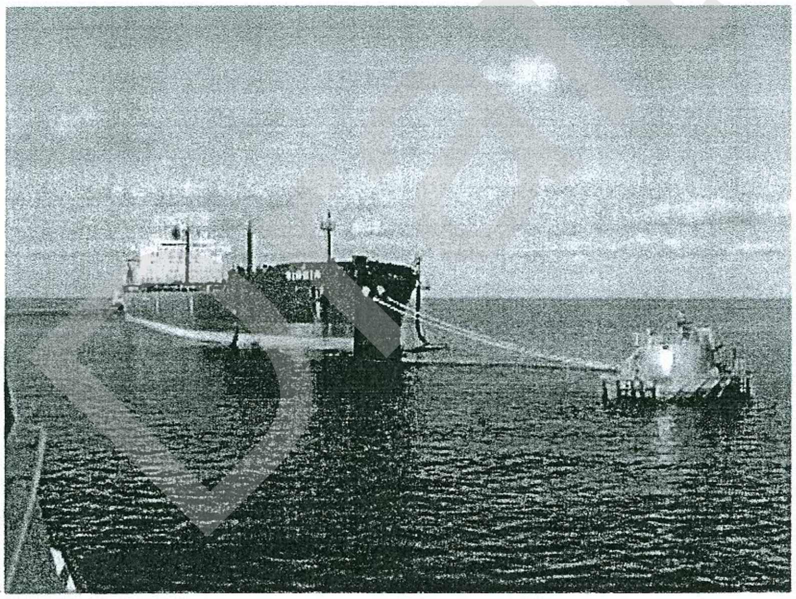
While it is envisaged that there will be 50 staff initially, accommodation capacity requirements are set at 60 POB. The difference is to allow accommodation of visitors and short term workforce. Capacity could be extended to 70 POB during Phase 1c. Any future accommodation upgrades will utilize portocabin style units located outside the main accommodation module on the FSO.

The FSO will have a Heli-deck, that will be suitable for S-92/S-61 type helicopters. There will also be a 10-ton crane that can be used to transfer equipment or personnel to the boats.

2.7.2 Moorings

Mooring is a key aspect of the overall FSO operational plan. A Catenary Anchor Leg Mooring (CALM) buoy based mooring system is proposed for the Block A Development (**Figure 2-9**). This system consists of a soft attachment to the buoy through use of a hawser. Reverse thrusters or a permanent tug are necessary in order to maintain distance from the buoy. The CALM buoy mooring system and FSO thrusters or tug provide the added benefit of quick release capability, allowing the FSO to move away to safer near-shore locations in the event of severe weather.

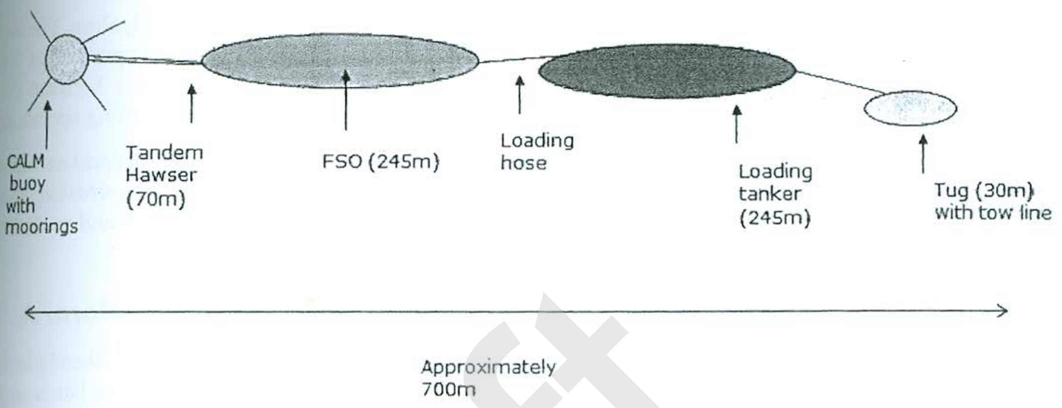
Figure 2-9: A CALM Buoy Based Mooring System



2.7.3 Dimensions

The following dimensions are approximate and may change subject to the final selected vessel. The schematic layout during offloading is shown in **Figure 2-10**.

Figure 2-10: Schematic Representation of the Calm Buoy Mooring System During Offloading



2.7.4 Crude Storage and Offloading

The crude is received from platform A via a single lazy S riser coming from the Pipeline End Manifold (PLEM). There is a Crude Oil Washing (COW) and an Inert Gas (IG) systems onboard the FSO. As sales occur on the FSO, a fiscal metering system with 25,000 bbls/hour offloading rate is also installed. Crude oil is offloaded by connecting a flexible hose with dry-couplings to a shuttle vessel. Loss of oil will lead to immediate shutdown of the transfer operation.

2.7.5 Produced Water

Produced water carried over into the crude that settles into the FSO will be transferred to the slops oil tanks. Oil is skimmed and oily water is transferred back to the Platform A for reinjection. A shuttle tanker will transfer the FSO produced water back to the platform at least during Phase 1A. Installation of an oily water pipeline may be considered for Phase 1b.

2.7.6 FSO Power Generation

The FSO has to generate its own electrical power and steam to maintain the crude oil in its storage tanks above the pour point. Estimates of consumption are given in Section 2.14.

2.7.7 Water Supply

The vessel has a desalination facility to produce fresh water. It is estimated that 35 tonnes/day of fresh water will be produced.

2.7.8 Exclusion Zone

There is a 500m exclusion zone around the FSO.

2.8 Pipeline, Pipeline End Manifold and Flowlines

2.8.1 Pipeline between Platform A and FSO

The produced crude is pumped from Platform A to the FSO via an 8" pipeline. The line is running approximately 3.5 km before tie-in to the Pipeline End Manifold (PLEM) upstream of the lazy S riser to the FSO. It is considered that 3.5 km provides a safe working distance between the production platform and FSO to reduce risk of collision during tanker offloading and lifting operations.

The pipeline is an API 5L grade X42 (or better) pipeline. It is insulated to prevent excessive product cooling as the crude is transferred between the platform and the FSO. It has corrosion protection systems such as fusion bond epoxy paint and sacrificial anode as the primary and secondary cathodic protection. The design pressure for pipeline is 1,325 psig at 250°F.

2.8.2 Pipelines between Wellhead Platforms and Platform A.

At the time of writing, only preliminary information on the future potential wellhead platforms is available and is subject to change. The flowline material will be API 5L, X42 or better and the same protection measures as for the pipeline between Platform A and the FSO will be implemented.

Numbers and diameters of flowlines may be revised during the later phases (for instance during FEED of Phases 1B and 1C and during detailed design of Phase 1B and 1C), however, the numbers that are shown in **Table 2-5** are considered to be the best estimates at the time of EIA writing.

The flowline installation schedule is correlated to the platforms installation schedule.

Table 2-5: Approximate Lengths and Diameters of Pipelines to be Installed during Phase 1b and 1c

Pipeline	Phase	Length– km	Diameter
Between Platforms B and D	1b	3.6	8"
Between Platforms C and D	1b	2.51	8"
Between Platforms F and D	1c	4.04	10"
Between Platforms D and A	1b	3.7	16"
Between Platforms J and B	1c	4.8	8"
Between Platforms E and B	1c	3.9	8"
Between Platforms H and G	1c	4.05	8'
Between Platforms G and F	1c	4.75	8"
Between Platforms I and C	1c	5.4	8"
Total Length		36.75	N/A

2.9 Drilling

2.9.1 Drilling Rigs

Two types of rigs are considered for this development project:

- jack-up rig (**Figure 2-11**) and
- tender-assist rig (**Figure 2-12**).

Figure 2-11: Jack-up Drilling Rig

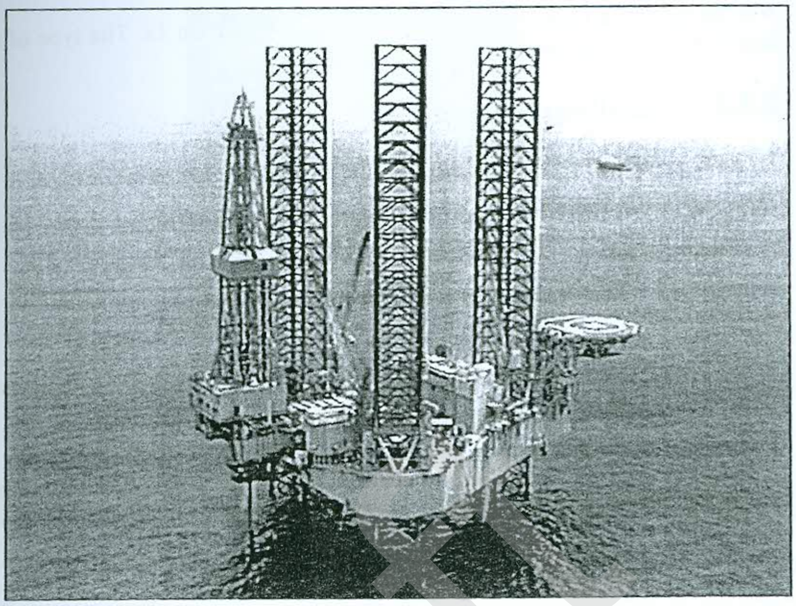
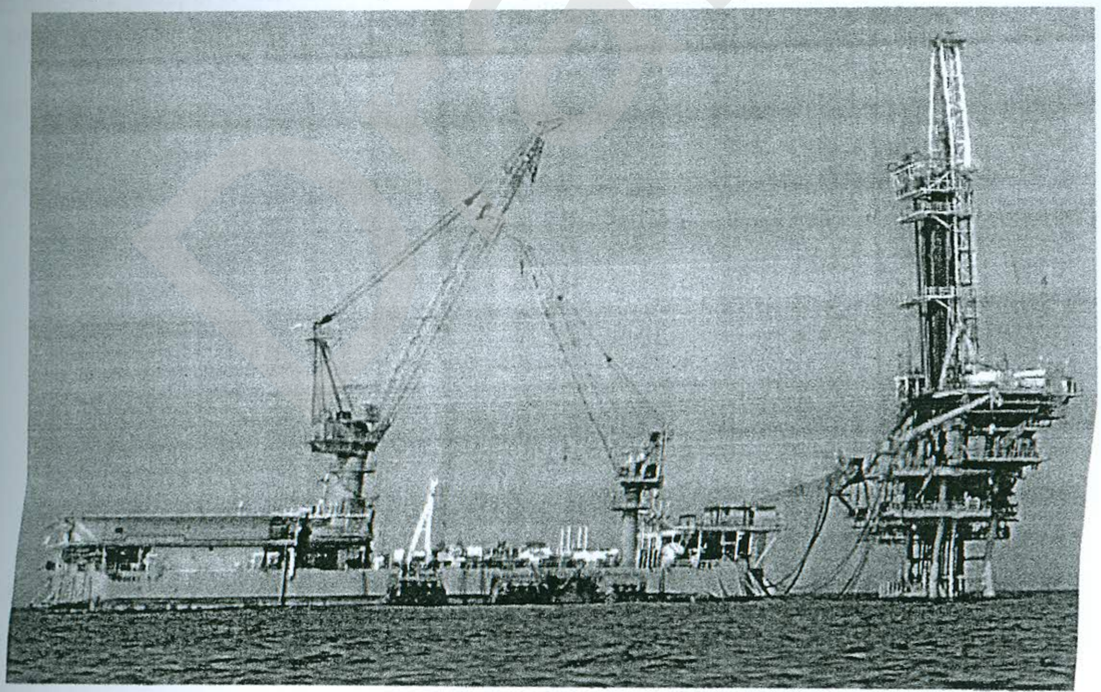


Figure 2-12: Tender Assist Drilling Rig



Both types of rigs are adequate for the water depths encountered within Block A. They are commonly used in the Gulf Of Thailand.

It is likely that a tender assist rig will be used for Phase 1a. The type of rigs to be used for Phase 1b and 1c has not been selected at this stage.

2.9.2 Drilling Process

2.9.2.1 Drilling Sequence

Wells will be drilled after the rig has been mobilized and set up on the platform.

The wells will be batch drilled. For each batch (likely about eight wells), one well section is drilled, the casing is installed and cemented before the next well in that batch is drilled. Drilling time per well is approximately 6.5 days.

2.9.2.2 Well Design

Two main well designs are planned for this project:

- A standard 3-string slimhole and
- A 4-string horizontal design.

The standard 3-string design is the most common design. It is a slimhole 3-string monobore and is designed for artificial lift using gas lift or ESP. A similar well design is also used for injection wells.

The 3-string slimhole well is composed of three sections:

- A 12¼-inch surface hole section that is drilled before the riser is in place; a 9⅝-inch casing[4] string is run and cemented inside the 12¼-inch hole after it has been drilled. The casing is set at about 305 meters (1,000 feet True Vertical Depth (TVD)).
- An 8½" intermediate section, is drilled once the riser is in place. It is drilled using a PDC bit[5] (**Figure 2-13**). A 7'' casing string is run and cemented inside the 8 ½" hole.
- A 6⅛" production section with 2⅞" tubing run to Total Depth (TD). The TD is no deeper than 3,200m TVD (10,500 feet TVD).

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[4] Casing helps prevent collapse of the well sidewall, inflow of reservoir fluids and loss of drilling mud. It separates the seabed from the well space.

[5] A PDC bit is a drilling tool that uses polycrystalline diamond compact (PDC) cutters to shear rock with a continuous scraping motion. PDC bits are effective at drilling shale formations.PDC bit are used to drill the intermediate and production sections.

Figure 2-13: Picture of a PDC Bit

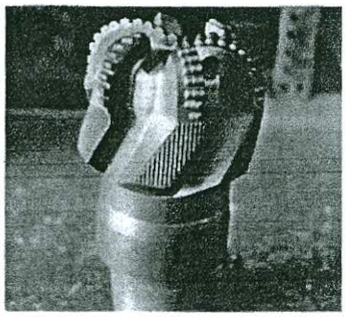


Table 2-6 summarizes the well design; a schematic of a gas lift well is represented in **Figure 2-14.**

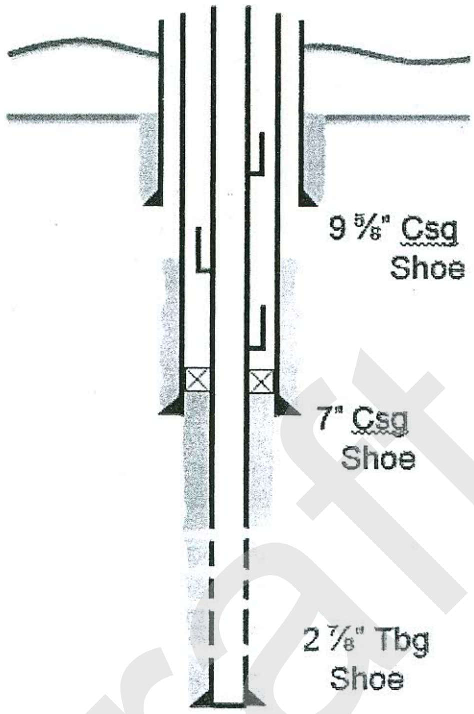
Table 2-6: Well Design of a Typical 3-String Slim Hole Well

Hole	Casing	Setting Depth (m TVD)
12¼" (surface)	9⅝"	305
8½" (intermediate)	7"	925-1,850
6⅛" (production)	2⅞"	3,200 maximum

Four string well designs become necessary when the well objectives cannot be achieved with a standard slimhole three string design. Several examples as to when a four string well design becomes necessary are:

- Shallow Hazard: The four string well is necessary in the case where the shallow hazard anomaly is so shallow that the kick tolerance of the subsequent hole section is not adequate to reach the required 7" casing setting depth.
- Deep Target: These deeper zones typically come with abnormal pressure regimes that exceed the kick tolerance capabilities of current three string well designs, hence the requirement for a four string well.
- 7" Into Horizontal Target Reservoir: The four string well design may be required for the 7" production casing to reach the horizontal well target reservoir.
- Horizontal or extended reach wells where the well design and/or completion requirements preclude using a three string well design.

Figure 2-14: 3-String Gas Lift Well Schematic



2.9.3 Mud, Cuttings and Cement

Drill cuttings are formation particles generated by the drill bit during the drilling process and vary in size from small slivers (less than 10 mm in length) to dispersed clays and ultra fine particulates (less than 0.002 mm). The nature of the cuttings depends on the geological formations drilled.

The function of the drilling mud is to provide circulation to remove cuttings from the hole, to cool the drill bit and to provide a hydrostatic head exerting greater pressures than expected from any formation which may be encountered to maintain well control.

2.9.3.1 Types of Mud

Mud is made up of weighting agents and a base fluid. This base fluid can be water or synthetic. Each section of the well requires a specific type of mud because pressure, temperature and geological characteristics change with depth of the well.

Surface Section

The surface section is drilled using Water Based Mud (WBM). The surface hole section is drilled before the riser is in place, and drill cuttings and mud are deposited onto the seabed near the wellhead since the drilling fluid exits the annulus at the sea floor. The casing is run and cemented to the mudline.

Intermediate Section

The intermediate section is drilled with Seawater. If hole cleaning problems are encountered, the sea water will be displaced with a Desco WBM. At the end of the section, a polymer WBM is circulated.

Cuttings and mud from this section are returned to the rig and discharged overboard.

Production Section

The production section (bottom section) is drilled with synthetic based mud (or Non Aqueous Fluid – NAF). It is planned to use Saraline 185V. Saraline 185V has been used extensively in the Gulf Of Thailand.

The NAF used for the 6⅛ inch production hole interval has an enhanced mineral oil external phase, which is an low toxicity mineral oil. The main components of the proposed NAF are calcium chloride in the brine phase, alkaline chemicals, barite to maintain the mud density, and Saraline 185V, which is a paraffin oil.

Cuttings and mud from the bottom section are returned to the rig and pass through the solid removal system, which consists of shale shakers which aim at separating the mud from the cuttings. The separated mud is then returned to the mud circulation system for re-use. Treated cuttings, which contain a small residual amount of attached mud are discharged at 1m below the surface.

The solid treatment system targets that no more than 9% Synthetic on Cuttings (SOC) remain. Once the NAF cannot be recycled because it has lost its technical properties, it is returned onshore.

Type of drilling fluids per section are summarized in **Table 2-7**. Typical compositions of the drilling mud are given in **Table 2-8**.

Table 2-7: Drilling Fluid Program for Standard Slim-hole Monobore Well Design

Hole Size	Depth (m TVD)	Drilling Fluid System
12¼"	305	Xantham Gum WBM
8½"	1,371	Seawater, Desco WBM and Polymer WBM
6⅛"	TD	Non Aqueous Fluid (NAF)

Table 2-8: Composition of Drilling Fluid by Section

	Additive	Property	Concentration	Units
Surface Section				
WBM	Seawater	Base Fluid	As Required	bbls
	Barite	Weighting Material	~ 36 at 9.2 ppg ~ 44 at 9.8 ppg	ppb
	Xantham Gum	Rheology	1.5 – 2.0 at 9.2 ppg ~ 2.5 at 9.8 ppg	ppb
Intermediate Section				
Seawater	Seawater	Base Fluid	As Required	bbls
Desco	Seawater	Base Fluid	1	bbls

	Additive	Property	Concentration	Units
	Barite	Weighting Material	~ 36	ppb
	PAC	Filtration	1 - 2	ppb
	DESCO	Thinner	0.2 – 0.5	ppb
	Xantham Gum	Rheology	1 – 2	ppb
PHPA	Seawater	Base Fluid	1	bbls
	Barite	Weighting Material	~ 36	ppb
	PAC	Filtration	1 - 2	ppb
	DESCO	Thinner	0.2 – 0.5	ppb
	Xantham Gum	Rheology	1 – 2	ppb
Production Section				
NAF	Primary Emulsifier	Primary Emulsifier	14 – 15 (S) 15 – 18 (H/URFL)	ppb
	Secondary Emulsifier	Secondary Emulsifier	0 – 3 (S) 3 – 8 (H/URFL)	ppb
	Gilsonite	Filtration Control	~ 4 (S) ~ 8 (H/URFL	ppb
	Pliolite	Filtration Control	0.5 – 2.5	ppb
	Organophylic Clays	Viscosifier	1 – 1.5	ppb
	Lime	Alkalinity	5 – 6 (S) 5 – 8 (H/URFL)	ppb
	Calcium Chloride	Salinity	18 – 20	ppb
	Saraline 185v	External Phase	~ 0.7	bbls/bbl
	Water	Internal Phase	~ 0.2	bbls/bbl
	Barite	Weighting Agent	As Required	ppb

Note: S is Standard and H/URFL when hot temperatures are encountered or when the mud is left extended times open hole

2.9.3.2 Drill Cuttings and Mud Quantities

The amount of drill cuttings can be estimated by calculating the volume of each section (i.e. from hole interval height and hole diameter). Generally, approximately 50% to 60% of the total well depths of a slimhole well is drilled with 6⅛ inch diameter hole; the amount of drilling mud and cuttings released from the slimhole drilling activities is less than a conventional hole drilling. It is estimated that on average approximately 148 m^3 of cuttings are generated per well. Estimated quantities of cuttings for each well per section and the total estimate for the Project are presented in **Table 2-9**.

Table 2-9: Estimated Average Mud and Cuttings Discharge

Bore Diameter (inches)	Well Interval	Discharge Method	Cuttings Volume Discharged (m^3)	Mud	
				Type	*Volume Discharged (m^3)*
12 ¼ "	Surface Hole	WBM with cuttings returned directly to seafloor	20	WBM	197
8 ½ "	Intermediate Hole	- Seawater with cuttings brought to a shale shaker on the drilling rig, then discharged to sea - WBM with cuttings brought to a shale shaker on the drilling rig, then discharged to sea	93	WBM	114
6 1/8"	Production Hole	NAF and cuttings brought to a shale shaker and centrifuge on the drilling rig, then cuttings and residual mud discharged to sea	35	NAF	90 (adhering to cuttings)
Total (for one well)			**148**		**311 WBM 90 SBM**
Total for one platform (Phase 1a)			**3,552**		**7,464 WBM 2,160 SBM**
Total Project (Phase 1a; 1b and 1c – 325 wells)			**48,100**		**101,075 WBM 29,250 SBM**
Note: this represents a worst case as infill drilling would produce less cuttings and use less mud					

2.9.3.3 *Cement*

Each steel casing string is cemented to form an effective seal between the casing and the formation. It has a specific slurry, with a density that is carefully selected to maintain well integrity. Most cement remains in the wellbore for the surface hole, while all the cement remains in the wellbore for the intermediate and production hole sections.

2.9.4 Well Completion

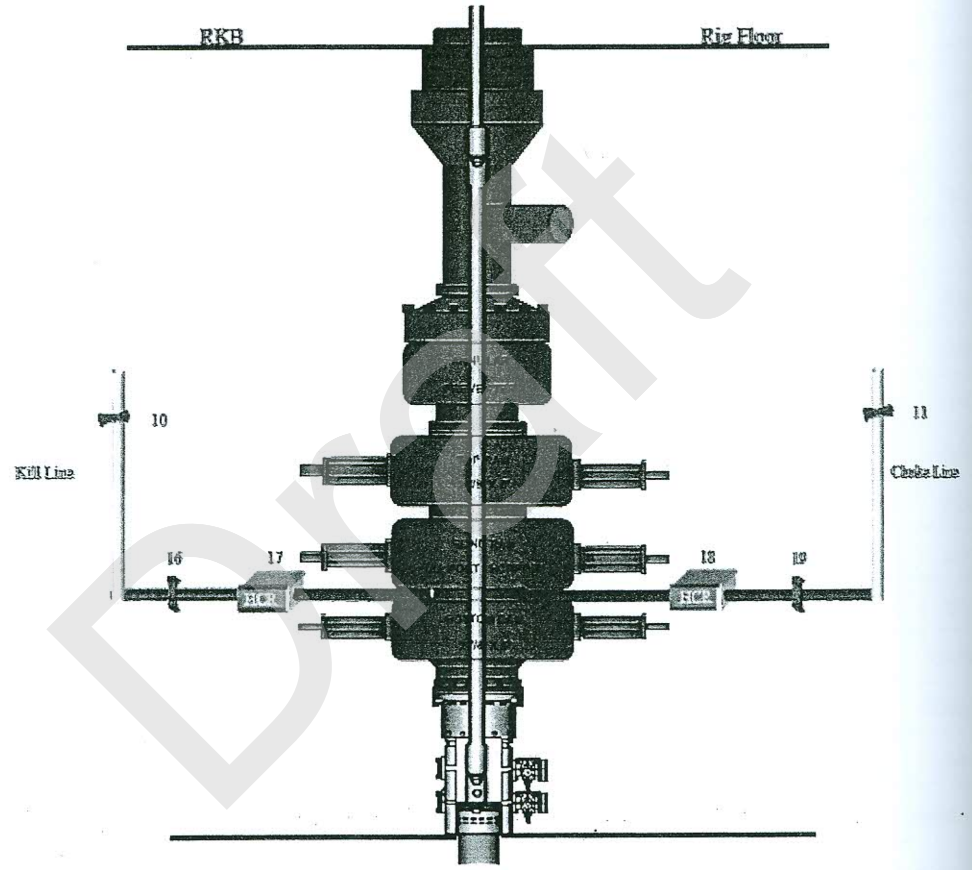
The wells are designed to accommodate either gas lift or Electric Submersible Pumps (ESP).

Gas lift mandrels are spaced along the completion tubing with the deepest mandrel set inside the 7-inch casing just above the 2⅞-inch by 7-inch packer to maximize the depth of injection (see **Figure 2-14.** A TRSV (Tubing Retrievable Safety Valve) is set 75 ft below the mud line. When an ESP is run, the TRSV must be set below the ESP to prevent formation fluid from entering the tubing when the TRSV closes.

A 6,500-psi unitized wellhead and Christmas tree will be used on all production wells.

A Chevron Class IV surface type Blow Out Preventor (BOP) system as shown in **Figure 2-15** will be used. This sytem is designed for wells in which Maximum Anticipated Surface Pressure (MASP) ranges from 5,000 psi to 10,000 psi.

Figure 2-15: Blow Out Preventor



2.9.5 Well Testing

No flowing well tests are planned to be conducted on the production wells.

2.9.6 Plugging and Abandonment (P&A)

Typical P&A activities in the GoT are aimed at slot recovery for additional in-fill drilling. The first objective is to provide a safe and secure abandoned well. The second objective is to provide a slot for safe infill drilling.

P&A work in the GoT is split in two phases. The abandonment activities in the initial phase (Phase I) consist of well integrity checks and tubing abandonment. They are conducted without a rig in place.

The primary activities include filling all well annuli, pressure testing, recording results and abandoning the tubing.

Abandonment activities in the final phase (Phase II) are executed with the drilling rig in place. The amount and type of work associated with a Phase II abandonment depends on the type of P&A planned for the given well slot.

2.10 Fabrication

Platform A (Phase 1a) will be fabricated in Thailand at CUEL fabrication yards. The fabrication yard has capabilities, and a working license for their activities in construction/ fabrication of offshore installations. The fabrication yard of Platforms B to J has not been selected at this stage. The fabrication is out of scope of this EIA study.

As described, the FSO vessel is an existing vessel that is converted to meet all project's applicable specifications. The shipyard at which the FSO is to be converted will be selected to comply with the International Maritime Standards and the specific requirements of the Project Owners. The conversion of the FSO is out of scope of this EIA study.

Procurement of materials and equipment for offshore pipelines will be from international vendors. Coating of offshore pipelines will be carried out in coating yards but these activities are outside of the scope of this EIA.

2.11 Installation, Hook up and Commissioning

During installation, personnel will be accommodated on the Derrick Lay Barge (DLB). During hook up and commissioning activities, the FSO will be on station to accommodate personnel required for these activities.

2.11.1 Seafloor Surveys

Prior to locating a drilling or platform site, seafloor/nearfloor analysis will be performed. The two surveys to be performed consist of a geophysical survey (shallow hazard gas assessment, analogue site survey analysis) and a geotechnical survey.

Shallow hazard gas assessment is accomplished by interpretation of shallow reflection data, such as existing 3-D seismic, along a planned borehole trajectory. Shallow gas is universally recognized in the GoT by strong and anomalous amplitude reflective events and is quite common. These are generally isolated in small areas and often times terminate against shallow subsea faults. Once these are interpreted, appropriate adjustments are made to the wellbore trajectory to avoid drilling through them.

Analogue site survey analysis is performed by a third-party contractor to assess the condition of the seabed and shallow strata. Seabed lithology and seabed obstacles or hazards are analyzed. Seabed samples can be taken during geotechnical surveys and analyzed. Overall interpretations are then made for the suitability of the site for jack-up rig or platform placement, and infield pipeline and flowlines routes.

Surveys relevant Phase 1a have been conducted already at the time of the EIA writing. Additional surveys may be required to inform Phase 1b and Phase 1c engineering.

2.11.2 Platform Installation

2.11.2.1 Production Platform Installation (Platform A and Potentially Second Production Platform)

The platform jacket is transported to the final location by a transport barge. The 4 leg jacket is lifted from the transport barge into the sea, up ended and lowered to the sea bed using the crane on the Derrick Lay Barge (DLB).

Once in position the piles are driven: P1/P2 piles are first driven, and then P3 and pile sections are welded and driven in turn for each of the four legs.

After all piles are driven, the topsides will be lifted and placed onto the piles in a single lift using a separate heavy lift crane barge. Once in place, the topside is welded onto the tops of the piles.

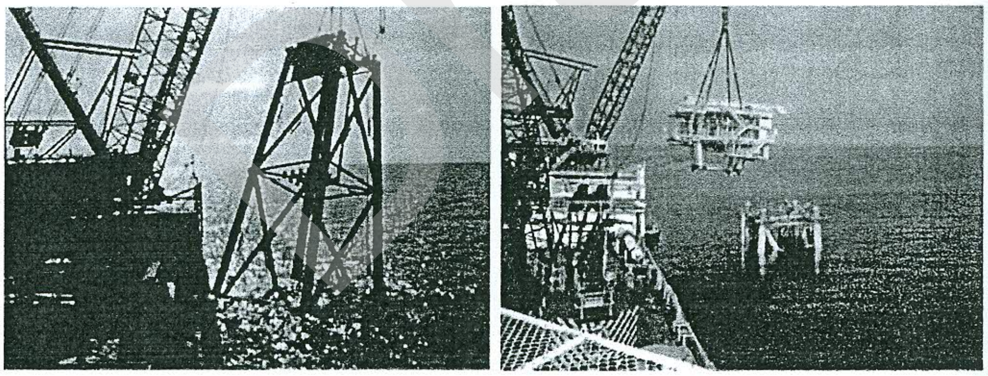
2.11.2.2 Wellhead Platforms Installation

The components of a wellhead platform (*i.e.*, jacket and topsides) are transported from the onshore fabrication yard on the same cargo barge. Installation sequences can be mainly divided into 2 steps:

- jacket installation and
- topsides installation.

Wellhead platform jacket installation consists of lifting and upending by a derrick barge (see **Figure 2-16**). Just as for the main platform, after the jacket is placed in the correct position, piles are driven through the legs. The topsides are then lifted and installed by a derrick barge and welded to the top parts of the jacket.

Figure 2-16: Installation of a Wellhead Platform



Source: Platong II EIA

2.11.3 CALM Buoy Mooring and FSO installation

The CALM Buoy mooring will be towed from its current location in Sattahip harbour, Thailand.

The installation of the mooring begins with the driving of six anchor piles into the seabed at the end of each of the six mooring chains. Once piling has been completed one end of each mooring chain is lowered to the sea bed and shackled to the respective pile. At the CALM Buoy end of the mooring chain, each chain is lifted in turn through the buoy to the respective chain stop. Once all six chains are connected to the chain stops, they are tensioned in turn until the mooring is in the correct location.

With the mooring in location, divers connect the lazy S riser to the Pipeline End Manifold (PLEM) and the other end to the CALM Buoy. Buoyancy tanks are installed at two defined locations along the riser to support the riser hose whilst in service.

The FSO will be towed to location by tugs from the conversion dry dock location. Once in location, the mooring hawsers will be connecting to the ship's mooring bollards. The floating hose from the CALM buoy will be lifted into location via the onboard crane and bolted to the receiving manifold. The ship is then ready for service.

2.11.4 Pipeline and Flowlines Installation

2.11.4.1 Installation

A Derrick Lay Barge (DLB) is required during pipeline installation.

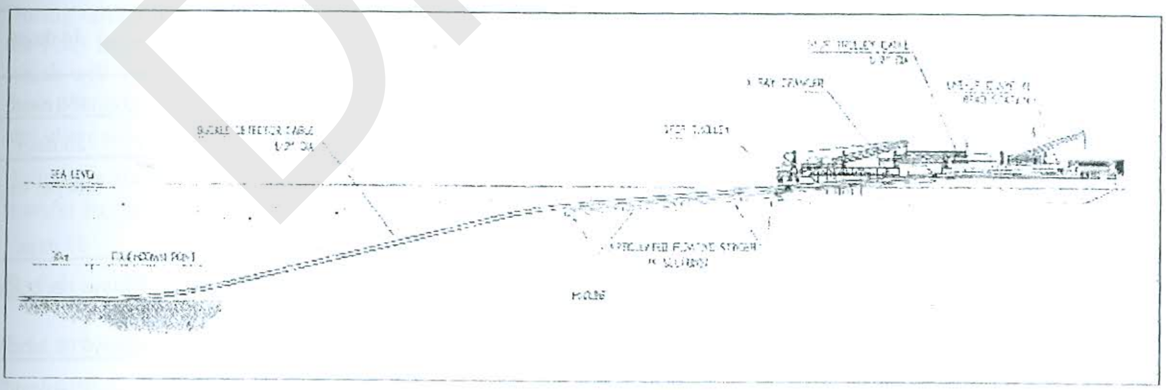
The DLB starts at the platform end by deploying a Dead Man Anchor (DMA) to maintain the correct tension on the pipeline during laying. The DLB lays down the PLEM at the FSO end of the pipeline in the target box and moves back to recover the DMA.

The pipeline is installed by pipe-lay barges by S-lay method (**Figure 2-17**). The pipeline is held in place and fed off the back of the barge via the stinger by a tensioning system. The tensioning system helps prevent the pipelines and flowlines from being overstressed during installation.

A Dynamic Positioning (DP) barge will be used to install the pipeline. A DP vessel maintains its location using thrusters and does not require anchors. Top ends of the risers on the jacket are then tied into the topside platform piping and pigging facilities.

It has not been decided whether a DP or an anchored barge will be used to install Phase 1b and Phase 1c flowlines.

Figure 2-17: Example of Pipeline Laybarge Operation



2.11.4.2 Commissioning

During the commissioning phase, hydrotest water will be used to verify the integrity of the pipelines. Chemicals are added to the hydrotest water. These chemicals consist of:

- dye
- oxygen scavenger
- biocide

2.12 Workforce

Installation and Drilling Activities

International and local contractors specializing in marine work will carry out surveys, install the platforms, drill wells, and install/test pipelines.

Production Phase

Core operations during production require 50 people during Phase 1a. Additional personnel may be mobilized for specific tasks, such as major maintenance work, or well servicing. The workforce for this project consists of contractors and Chevron staff. Approximately 30 people total will be needed to run the ship and 20 people total to run the facilities. These numbers cover both day and night shifts. To accommodate visitors, as described above, the capacity on the FSO will be 60 POB. Additional personnel may be required for Phase 1c. Capacity on the FSO may be increased to 70 POB.

The new workforce for the Apsara development project will be recruited in advance to familiarize them with the new equipment. The FSO will be leased and not operated by Chevron. Plans related to the Shorebase support operations are not fully defined at this stage.

Where appropriate, the use of local business firms and employees will be a priority for Chevron and Partners. Local Content and Business Development are part of Chevron's business strategy to develop national supplier capability. Personnel will typically be a mix of Cambodian nationals, regional staff and expatriate personnel.

A tentative manning summary is provided in **Table 2-10**.

Table 2-10: Manning Summary

Activity	Number of Workers	Time Period
Installation of Offshore Production Platform	250 on DLB +40 on support vessels	10 days
Installation of Pipeline and CALM Buoy (Phase 1A)	250 on DLB + 40 on Support Vessels	14 days
Offshore Drilling Operations – Phase 1a	140	180 days
Platform A Hook Up and Commissioning	20	28 days
Installation of Flowlines	250 on DLB + 40 on Support Vessels	1km per day 37 days
Wellhead Platforms	250 on DLB + 40 on Support Vessels	7 days per platform 63 days for nine WHP
Offshore Drilling Operations – Phase 1b and 1c	140	1620 days
Offshore Production Operations	50 to 60 x2 = 100 to 120 Potentially 70 during Phase 1c	15 years*
Onshore Supply Base	5	30 years
*for FSO management and Platform operation in Apsara field only (Estimates subject to change during detailed design).		

2.13 Onshore Support

2.13.1 Shorebase

During installation, shorebases in Thailand and in Sihanoukville will be used.

During operations and drilling, the project team will use a shorebase located within or close to Sihanoukville Autonomous Port. Plans related to heliports and other shore support are currently being assessed by the project team at the time of the EIA development.

2.13.2 Transportation – Vessels and Helicopters

2.13.2.1 Installation

All of the material and equipment for installation is expected to be imported and will be transported by barges directly to the installation site.

2.13.2.2 Drilling and Operations

Aviation transportation services will be sourced either locally by qualified suppliers, or sourced internationally if none are available. The services are expected to be based out of either Sihanoukville or Phnom Penh. The Project team is evaluating options at the time of EIA writing.

Personnel for production operations will be transferred by helicopter or crew boat, with a crew change every 4 weeks.

Plans related to transportation of equipment are under review by the project team. It is expected that products and/or materials developed locally be transported via land transportation to a shore base location (Sihanoukville) where they will ultimately be transferred offshore via supply vessels.

During drilling there is likely to be two supply boats in the field. During typhoon season, an additional work boat will be required to standby a tender rig.

During operations, if a non Dynamic Positioning FSO is chosen, a tug will be on standby to prevent the FSO from drifting onto the CALM buoy. There will also be a small vessel full time in the field which will serve as a crew boat between the FSO and the Platforms. Boat transfers will only occur during suitable weather conditions. A supply vessel will carry diesel, potable water, domestic water, and other supplies from Sihanoukville to the FSO.

Helicopter transport or crew boats may be used for crew changes. Crew boat access shall be by crew transfer basket, using the facility crane.

2.14 Power Generation / Fuel Consumption

2.14.1.1 Drilling Rig

The drilling rig will use Marine Diesel Oil (MDO) to run the engines. Estimated consumption are provided in **Table 2-11**.

Table 2-11: Estimated Marine Diesel Oil Consumption on Drilling Rig

Source	MDO Consumption (MT)	MDO Consumption (m^3)
Total daily Rig MDO Consumption	12.4	13.5
Phase 1a. Total rig MDO Consumption for platform A	2,232	2,430
Phase 1b (3 additional platforms)	6,696	7,318
Phase 1c (6 additional platforms) Total rig MDO Consumption	13,392	14,636

MT: Metric tonnes m3: cubic meters

Assumptions: MDO density: 0.915; Duration of e Drilling operations for each platform: 180 days

2.14.1.2 *Processing Platform*

The platform will use associated dry gas as a fuel gas source. Fuel gas consumption estimates are provided in **Table 2-12.**

Table 2-12: Estimated Fuel Gas Consumption

Source	Fuel gas Consumption (MMSCFD)
Generator 1 engine	0.3
Generator 2 engine	0.3
Gas lift compressor engine	0.3
Total	0.9

Assumption: full load.

In addition, there is a diesel storage system that is sized to enable a run time of up to 6 days at maximum diesel consumption to maintain production during times when personnel cannot access the platform such as periods of bad weather. The system will be designed to automatically switch to the diesel powered generator should either of the gas engine units fail or are down for maintenance.

When the diesel system of the fuel gas generator is in use, it is expected that between 90 and 320 L per day will be consumed. The consumption depends on whether it is 100% diesel or up to 70% gas. Based on past experience, it is estimated that the annual diesel consumption on Platform A should average 30 days per year. Data is summarised in **Table 2-13.**

The crane will be diesel driven. It is estimated to use approximately 40L per day. Crane and dual generator are the only sources of diesel consumption on the platform.

Table 2-13: Estimated Annual Diesel Consumption on Production Platform

	Estimated Maximum Daily use (L)	Estimated Maximum Annual Diesel Use (m^3)	Estimated Maximum Annual Diesel Use (MT)
Dual fuel generator	7,680	203.4	186.0
Crane	40	14.6	13.4
Total diesel consumption	7,720	218.0	200.0

Assumptions: Dual fuel generator: Maximum daily use represents 100% diesel consumption; 30 days per year;

Crane: 365 days a year. Estimated numbers are subject to change. Marine diesel oil density: 0.915

2.14.1.3 Wellhead Platforms

On the wellhead platforms, power is provided by 35KW reciprocating engine powered generation units. The duty unit is a gas engine driven unit with a standby diesel engine driven unit of the same capacity. The units are designed to switch over automatically should either unit shutdown. **Table 2-14** indicates estimated fuel gas consumption on each wellhead platform. If the diesel engine powered generator is in use, the expected daily consumption of diesel at full load is 530 litres/day. It is expected that full load consumption will occur an average of 20 days a year as shown in **Table 2-15**.

Table 2-14: Estimated Consumption of Fuel Gas per Wellhead Platform

Source	Fuel gas Consumption (MMSCFD)
Fuel gas	0.34
Instruments gas	0.61
Total gas consumption	0.95

Table 2-15: Estimated Annual Consumption of Diesel per Wellhead Platform

	Estimated Maximum Daily use (L)	Estimated Maximum Annual Diesel Use (m^3)	Estimated Maximum Annual Diesel Use (MT)
Generator	530	10.6	9.7
Crane	40	14.6	13.4
Total diesel consumption per WHP	570	25.2	23.0

2.14.1.4 FSO

The FSO burns Intermediate Fuel Oil and (IFO) and Diesel Oil (DO). The numbers given in **Table 2-16** assume a dynamic position capable vessel – which does not require a dedicated tug and therefore represent a worst case in terms of fuel consumption. These numbers are preliminary and subject to change. Based on Chevron's experience in the Gulf Of Thailand, it is estimated that on average there are 5 days of severe weather which may affect or suspend offloads and require higher fuel consumption during the year.

Table 2-16: Estimated Daily and Annual Consumption on the FSO

	Consumption	
Type of fuel	**Diesel Oil**	**Intermediate Fuel Oil**
During calm times	3 Tonnes / day	2,5 Tonnes / day
During severe weather and during offloads	5 Tonnes / day	20 Tonnes / day
Annual consumption	1105 Tonnes / year	1000 Tonnes / year

2.14.1.5 *Supply Vessels and Helicopters*

Table 2-17 summarizes vessels fuel and **Table 2-18** summarizes helicopters fuel requirements per phase. The worst case would be considered two processing platforms and eight wellhead platforms. For the purpose of the EIA, this worst case has been considered.

Table 2-17: Installation and Supply Vessels Marine Diesel Fuel Requirements (Estimates)

Phase	Number of Vessels	Time (days)	MDO Consumption (MT)	MDO Consumption (m^3)
1a - Installation of Offshore Platform A	DLB, 2xTransport Tug + support vessel, supply vessel 2 trips	10	363	397
1a – Hook Up and Commisioning - Platform A Hook Up and Commissioning	Crew Boat, Support Vessel, supply vessel 4 trips	28	342	374
1a - Installation of Pipeline and CALM Buoy (Phase 1a)	DLB, 1xTransport Tug, supply vessel 2 trips	10	252	275
Total 1a – Installation and HUC Consumption			957	1,046
Installation of one flowline (Phase 1b and 1c)	DLB, 1xTransport Tug	4	86	94
1b - Installation of phase 1b flowlines	DLB, 1xTransport Tug	12	258	282
1c - Installation of phase 1 c flowlines	DLB, 1xTransport Tug	24	516	564
1b and 1c - Installation of 1 Wellhead Platform	DLB, 1xTransport Tug + Support vessel, supply vessel 1 trip	7	200	219
1b – Installation of 3 wellhead platforms	DLB, 1xTransport Tug + Support	21	600	657

Phase	Number of Vessels	Time (days)	MDO Consumption (MT)	MDO Consumption (m^3)
	vessel, supply vessel 1 trip			
1c – Installation of 5 wellhead platforms	DLB, 1xTransport Tug + Support vessel, supply vessel 1 trip	35	1,000	1,095
1b and 1c - Hook up and commissioning of one Wellhead Platforms (Platforms (B to E and G to J))	Crew Boat, Support Vessel, supply vessel 3 trips	14	179	196
1b Hook up and commissioning of three Wellhead Platforms	Crew Boat, Support Vessel, supply vessel 3 trips	42	537	588
1c - Hook up and commissioning of five Wellhead Platforms	Crew Boat, Support Vessel, supply vessel 3 trips	70	895	980
1c - Installation of second Production Platform	DLB, 2xTransport Tug + support vessel, supply vessel 2 trips	10	363	397
1c – Hook Up and Commisioning – Second production Platform Hook Up and Commissioning	Crew Boat, Support Vessel, supply vessel 4 trips	28	342	374
Total 1b Installation and HUC Consumption			**1,395**	**1,524**
Total 1c – Installation and HUC Consumption			**3,116**	**3,405**
1a- Drilling Offshore Drilling Operations Platform A	2 supply vessels	180	2,965	3,240
1b Drilling Offshore Drilling Operations	2 supply vessels	540	8,895	9,720
1c Drilling Offshore Drilling Operations	2 supply vessels	1,080	17,785	19,440
Offshore Production Operations – Phase 1a annual	1 supply vessel 1 crew boat Total	104 365	856 2605 3461	936 2,847
Offshore Production Operations – other phases	1 supply vessel 1 crew boat Total	104 365	856 2605 3461	936 2,847

Assumptions:

DLB(Lewek) = 18,000lts/day ; DSV(Commander) = 14000lts/day ; ISV(KNE) = 4500lts/day

Crewboat = 7,800Lts/day ; Supply Boat = 9,000lts/day ; AHT = 9500lts/Day ;Transport Tug = 8000lts/day

While it is assumed that the additional Processing platform will be Platform F, this may change as project develops.

3 AHSTs (anchor handling, suppply, tugs) are used to bring a rig onto and off location and to set/retrieve anchors. In addition an AHST will be required to be on standby if a Tender Rig is used during typhoon season. 2 vessels at all time have been assumed for the purpose of estimating emissions.

Table 2-18: Helicopter Fuel Requirements (Estimates)

Phase	Number of Helicopter Trips	Fight Time (hrs)	Consumption (MT)	Consumption (m^3)
1a - Installation Installation of Offshore Platform A	6	9	4.5	5.7
1a- Installation Installation of Pipeline and CALM Buoy (Phase 1a)	3	4.5	2.3	2.9
1a – Installation Platform A Hook Up and Commissioning	18	27	13.5	17.2
Total 1a- Installation and HUC			20.3	25.8
1b and 1c – Installation Installation of 1 Wellhead Platform or 1 Central Processing platform	6	9	4.5	5.7
1b- Installation of 3 wellhead platforms	18	27	13.5	17.1
1c – Installation of 6 platforms Platforms	36	54 81	27	34.2
1b and 1c - Installation Installation of one flowline (Phase 1B and 1C)	3	4.5	2.3	2.9
1b - Installation Installation of three flowlines	9	13.5	6.9	8.7
1c – Installation of 6 flowlines	18	27	13.8	17.14
1b – 1c Hook up and commissioning of one Platforms (B to J)	18	27	13.5	17.2
1b –Hook up and commissioning of three Wellhead Platforms	54	81	40.5	51.6
1c Hook up and commissioning of five Wellhead Platforms and one central processing platform	108	162	81	103.2
Total 1b –Installation and HUC			60.9	77.4
Total 1c Installation and HUC			121.8	154.7

Phase	Number of Helicopter Trips	Fight Time (hrs)	Consumption (MT)	Consumption (m^3)
1a – Drilling Offshore Drilling Operations Platform A	104	156	78	99.1
1b – Drilling Offshore Drilling Operations – phase 1b – 3 platforms	312	458	234	297.3
1c – Drilling Offshore Drilling Operations – phase 1c – 6 platforms	624	916	468	594.6
Offshore **Production** Operations – **Phase 1a annual**	70	105	52.5	66.7
Offshore Production Operations – **Phase 1b annual**	78	117	58.5	74.3
Offshore Production Operations – **Phase 1c annual**	91	136.5	68.2	86.7

Assumptions:

- flight time between SHV heliport and Block A is approximately 0.75hrs (1.5 hrs return).
- Density of jet fuel: 0.787kg/liter

2.15 Flaring

Production consists of oil, water and gas. As discussed in the previous section, the three substances will be separated on platform A. The gas will be used as fuel gas on the platform and for gas lift operations, with the remaining gas being flared at least during Phase 1a. For phase 1b and 1c, the feasibility of reinjecting the associated gas will be studied.

2.15.1 Phase 1a

Initially, for the first year, there will be small volumes of gas which will be mostly used for fuel gas and gas lift requirements, therefore the expected flaring rate is less than 2MMSCFD. The volume of associated gas is expected to built up during years 2 and 3 as shown on **Table 2-19**. If high GOR reservoirs are found, the flaring rate could reach approximately 5.7 MMSCFD. As indicated in section 2.1, all calculations in the EIA are based on EV values.

2.15.2 Phases 1b and 1c

The feasibility of reinjecting the gas will be studied. Gas reinjection would most likely be done by installing a stand alone gas injection skid on platform A.

Even if there will be no continuous routine flaring during Phase 1b and Phase 1c due to reinjection, a flare must be on the platform for safety reasons. These reasons include emergency flaring for the prevention of loss of life as a result of encountering conditions outside the normal operating design. The flare will most likely have a pilot ignition system. For this system, the flare tips would be fitted with pilot burners in which a small amount of gas would be continuously burned.

2.15.3 Estimated Flaring Volumes

Estimated flaring volumes are summarized in **Table 2-19**.

Table 2-19: Estimated Flaring Volumes

Year	Estimated Maximum Flaring Volumes (MMSCFD)
Phase 1a – Year 1	2.0
Phase 1a – Year 2	2.5
Phase 1a Year 3	3.5
Phase 1b – 1c*	2.0

Assumption: gas reinjection from phase 1b.

2.16 Atmospheric Emissions

Project activities will create air emissions. During installation and drilling, the main source of air emissions will be from the vessels and rig engines. Particulate emissions (dust) will also arise during bulk material transfer operations through the system vents. Examples of bulk transfer products are barite and cement. Key emissions include carbon dioxide (CO_2), carbon monoxide (CO), sulphur dioxide, (SO_2), nitrogen oxides (NO_x), methane (CH_4), and nitrous oxides (N_2O). N_2O, CH_4 and CO_2 are considered greenhouse gases.

During production, the source of air emissions will be from flaring, and diesel/gas engines used on the platform, FSO, and support vessels. Other releases to the atmosphere will arise as a result of fugitive emissions of methane and non-methane hydrocarbons from a range of sources including, fuel bunkering, and transfer operations. Venting on the production platform is mainly from the open drain system. Other sources of open venting are the sump cassion, diesel storage tank, diesel day tanks, chemical storage tanks, chemical tote tanks, lube oil tanks. The recovered hydrocarbons from the open drain tank will be pumped directly to the closed drain system. The amount of GHGs emitted are considered to be very small due to the high flash point of these inventories (low vapors).

Emissions during decommissioning will be mostly from engines (marine vessels) used to support the removal of the facilities.

The quantification and impact assessment associated with atmospheric emissions are provided in Chapter 5.

2.17 Waste Generation

2.17.1 Liquid Waste

The main liquid waste streams that are expected from the project consist of:

- produced water;
- sewage (black and grey water;
- drainage;
- hydrotest water (required during the commissioning phase) and
- cooling water
- brine water

As seen in Section 2.6, produced water will be reinjected, therefore is not included in this section.

2.17.1.1 Sewage - Black and Grey Water

The sources of sewage are the lavatory facilities; the sources of domestic wastewater are bathrooms, washbowls, washing areas and kitchens or galleys located on the drilling rigs, on the FSO, and on the installation and support vessels.

Sewage from the accommodation block on the FSO, the drilling rig and any installation and support vessels with a capacity more than 400 gross tons will be treated by the onboard sewage treatment plants before being discharged overboard in line with MARPOL 73/78 Annex IV regulations. The sewage treatment system is certified by the International Maritime Organization (IMO). It treats and disinfects sewage before discharge.

Sewage generated from vessels with a capacity less than 400 gross tons, such as a crew boat, will be discharged directly into the sea without treatment as per MARPOL 73/78 Annex IV requirements.

Domestic wastewater is discharged directly to the sea in accordance with applicable regulatory requirements.

It is estimated that the volume of sewage and domestic wastewater generated are approximately 0.08 and 0.12 m^3/person/day respectively.

Table 2-20 summarizes sewage and domestic wastewater estimated volumes to be generated during each phase of the project.

Table 2-20: Estimated Sewage and Domestic Wastewater Production per Phase

Activity	Number of Workers	Estimated Daily Volumes of Sewage (m^3/day)	Estimated Daily Volumes of Domestic Wastewater (m^3/day)
Installation of Offshore Platform	250	20	30
Installation of Pipeline and CALM Buoy (Phase 1a)	250	20	30
Installation of Flowlines	250	20	30
Platform Hook Up and Commissioning	20	1.6	2.4
Drilling	140	11.2	16.8
Offshore Production Operations	60	5.6	8.4

Assumption: 0.08 of black water and 0.12 m3 of gray water per person per day. 60 POB average for all phases.

2.17.1.2 Drainage

On the drilling rig, supply vessels and FSO, all drainage from designated machinery spaces is routed to a waste oil storage tank. Collected wastewater is then passed through an oil water separator to meet MARPOL 73/78 discharge standard. Treated water whose oil content is less than 15 ppm is discharged to the sea. Separated oil is collected in the slop tank.

Drainage collected on wellhead platforms and the production platforms during the operation phase will be managed by open and closed drainage systems. The open drains system collects and treats rain and wash down water from each deck and the closed drains system collects hydrocarbon drained from vessels and equipment and returns it to the process. The closed drain system collects hydrocarbon in a closed system, not open to the environment, whereas, the open drains system is open to the environment, collecting rain and wash down water and returning it to the sea.

On the wellhead platforms, deck drainage is collected in open drains on each deck and directed to an Open Drains tank. A gravity separator inside the tank provides oil/water separation. The collected oil from the open drains tank is pumped back into the process via the Closed Drain drum. On wellhead platforms, separated water is discharged directly to the sea from the Open Drains tank.

On Platform A, the open drains system is split into hydrocarbon and non hydrocarbon drains drains. Non hydrocarbon drains collect water from areas where hydrocarbon cannot be present (e.g. around control room etc) and the hydrocarbon drains collect water from main process areas where some hydrocarbon could be present. The hydrocarbon drains system directs water to the Open Drains tank which separates and collects captured hydrocarbon in a gravity separator. Hydrocarbon is returned to the process via the Closed Drain Drum and water is discharged to the sea via a drains caisson. The non hydrocarbon deck drains discharge directly to the drains Caisson. The drains caisson includes equipment which can indicate the presence of, and return any hydrocarbon back to the process should it accumulate in the caisson over time. Only clean water is discharged directly to the sea.

2.17.1.3 Hydrotest Water

Following installation, the pipelines will be hydrostatically tested as per the requirements of the design codes, to a pressure of 1.25 times the Maximum Allowable Operating Pressure (MAOP). Risers will be tested to a pressure of 1.4 times the MAOP. If the pipelines and/or risers fail the hydrostatic test, leaks will be located and repaired.

The hydrostatic test media will be seawater that has an added oxygen scavenger as well as a biodegradable and environmentally acceptable biocide. A dye will also be added to assist with leak detection.

Types of chemicals used for this operation include Blacksmith O-3670R which is a mixture of oxygen scavenger and biocide at a concentration of 750ppm, and Fluorescent LT Dye at a concentration of 40 ppm. MSDS are available in **Appendix 3**. Chevron has given careful consideration to the selection of chemicals and various factors including toxicity, degradability and biological fate while choosing dose concentrations in accordance with good industry practices.

Hydrotest water from the main pipeline between Platform A and the FSO will be discharged directly to the sea. Hydrotest water from the flowlines between the Wellhead platforms will be discharged to the sea.

Estimated volumes of hydrotest water are shown in **Table 2-21**.

Table 2-21: Estimated Volumes of Hydrotest Water to be Discharged

Pipeline	Phase	Volume of Hydrotest Water (m^3)
Between FSO and Platform A	1a	109.9
Between Platforms B and D	1b	113.0
Between Platforms C and D	1c	78.8
Between Platforms D and A	1b	464.7
Between Platforms F and D	1c	198.2
Between Platforms J and B	1c	150.7
Between Platforms E and B	1c	122.5
Between Platforms H and G	1c	127.2
Between Platforms G and F	1c	149.1
Between Platforms I and C	1c	169.6

2.17.1.4 Cooling Water

There will be two cooling systems on the FSO: a closed loop freshwater system and an open loop seawater system.

Seawater will be lifted from below the sea surface. It will be used in the freshwater maker system and also as cooling water for the closed-loop fresh water system before being pumped overboard.

No chemicals will be added to the seawater open loop system that will be discharged overboard. Chemicals (anticorrosion and descaling) will be added to the closed loop fresh water system only. As it is a closed loop, it will not be discharged overboard.

At the time of writing, the depth of water intake, and the approximate volume of seawater to be lifted are unknown. These volumes and depth are dependant on the FSO that will be selected.

A mesh will be fitted to the inlet on the seawater lift caisson to prevent ingress of marine organisms.

Cooling water in the Gulf of Thailand is usually discharged at 30°C +/- 2°C.

2.17.1.5 Brine Water from Potable Water Maker

A small amount of seawater will be desalinated to be used as freshwater. The desalination process reduces the dissolved salt content. There are two products from a desalination process: a low salinity water (freshwater) to be used on the FSO and a brine, which is a concentrated salt solution.

Consequently, a small amount of brine will be discharged from the freshwater maker on board the FSO. The brine will be discharged in the seawater and will be rapidly diluted in the Gulf of Thailand. It is expected that the waste stream will be about 30-40% of the required feed water, which is estimated to be around 25- 30 MT per day. The estimated volumes of brine will therefore be around 12 MT per day. The brine is discharged at about 35°C.

The discharge of brine in offshore waters is insignificant and therefore not considered further in the EIA.

2.17.2 Solid Wastes

Solid wastes from the proposed project can be classified as follows:

- Food Waste;
- Non-hazardous waste;
- Hazardous waste.

Food Waste

Food waste from kitchens and canteens will be kept separate from non-food waste (such as packaging). As per MARPOL Annex V regulation (Garbage), food waste will be macerated in an offshore macerator and discharged overboard. Discharged food particles should not be larger than 25mm.

Non-Hazardous Waste Management

Non-Hazardous Waste includes packaging, paper, plastic, and other uncontaminated materials. Non hazardous waste will be generated from canteens, living quarters and offices, and project processes. Non hazardous waste will be transferred from the drilling rig, supply vessels, platforms and FSO to the shorebase at Sihanoukville Autonomous Port and disposed of by a licensed and COPCL approved waste contractor.

Hazardous Solid Waste Management

Main hazardous wastes expected to be generated include oily rags; used oil; paint waste; electronic waste; spent lube oil, greases and hydraulic fluids; batteries; fluorescent tubes; and spent metallic filters.

Hazardous waste will be recycled back to the process when feasible (used oil). Sludge will be reinjected if feasible or stored offshore until shipped to a disposal facility. All other hazardous waste will be segregated from non hazardous waste, brought back to shore and disposed of by a licensed and COPCL approved contractor.

Waste streams that cannot be safely disposed of in Cambodia (such as mercury contaminated waste) will be exported overseas following applicable regulations for safe and environmentally acceptable treatment.

Waste Quantities

Estimated volumes of solid waste are provided in **Table 2-22** and are based on actual volumes from similar types of operations in the GoT.

Table 2-22: Preliminary Solid Waste Quantities – Main Streams

Type of Waste	Estimated Annual Quantity (kg)
Non hazardous	
Combustible trash/office waste	106,000
Empty sacks	248
Spent hose	3,040
Wood scraps	883
Empty drums	4,215
Non contaminated scrap metal	46,531
Hazardous	
Oily rags	3,281
Used lube oil / hydraulic oil	13,789
Electronics waste	240
Fluorescent tubes and ballast	13
Lead acid batteries	605
Paint waste	629
Hg contaminated oily sludge*	89,000
Spent metallic filters	448

* Not expected during the first years of the development.

This preliminary estimate is subject to change. At the time of EIA writing, the team is developing the Waste Management Plan.

2.18 Operational Excellence - Health, Environmental, Safety and Reliability Management

Chevron assess and takes steps to manage potential risks to the employees, the contractors, the public and the environment within the following framework of its Operational Excellence Management System (OEMS) and OE Expectations.

2.18.1 Tenets of Operation

To achieve and sustain Chevron's objectives, a culture has been developed where everyone believes all incidents and operating disruptions are preventable and that "zero incidents" is attainable.

Tenets are a code of conduct used by employees and contractors as a tool to guide daily decisions. Leaders play an important role in reinforcing behaviours consistent with the tenets. The Tenets of Operation are based on two key principles:

- Do it safely or not at all.
- There is always time to do it right.

COPCL will deploy the Tenets of Operation to provide a foundation for an Operational Excellence culture at the Apsara field.

Always:

- Operate within design and environmental limits.
- Operate in a safe and controlled condition.
- Ensure safety devices are in place and functioning.
- Follow safe work practices and procedures.
- Meet or exceed customer's requirements.
- Maintain integrity of dedicated systems.
- Comply with all applicable rules and regulations.
- Address abnormal conditions.
- Follow written procedures for high-risk or unusual situations.
- Involve the right people in decisions that affect procedures and equipment.

2.18.2 Operational Reliability and Maintenance

The general operating plan is designed to comply with all applicable laws and regulations. Production platforms are manned by a minimum of two personnel. All equipment apart from the gas lift compressors and ESP's are designed with back up (duty/standby) for reliable operations. In most cases this equipment will automatically start up reducing the requirement for operator intervention. Sufficient instrumentation will be provided to alert the operator of an abnormal condition, and if this condition continues to deteriorate, then processing and platform operations will shut down.

Future wellhead platforms are not manned. Routine maintenance operations will be controlled from processing platforms. They include:

- Well flow rate adjustments
- Switching wells into/out of the test separator
- Monitoring and recording well test data
- Opening and closing individual wells
- Monitoring well flow rates and platform flow rates

- Performing well blow downs
- Monitoring levels of corrosion inhibitor, pour point depressant, etc.
- Monitoring ESPs
- Monitoring casing pressures
- Perform platform shutdown and restart for limited events
- Monitoring power generators

Future wellhead platforms will require periodic operator visits depending on the specific requirements. Operator vistis will be required for start up after a platform shutdown (either emergency or remote shutdown), preventive maintenance (PM) tasks on the platform, and well servicing, to name a few. Major operations such as major maintenance and well servicing will be planned events with additional personnel provided accordingly. There will be a permanent supply boat in the field capable of operating 24/7.

The facilities are designed to allow routine maintenance of equipment without shutting down the entire platform.

Preventative maintenance tasks are scheduled and incorporated in daily work planning. It is envisioned that only minor repair work is to be done offshore. Anything that cannot be easily repaired will be replaced and the defective equipment will be sent to shore for repair.

Activities will include appropriate machinery maintenance as recommended by suppliers in addition to preventative activities to mitigate long term degradation. Examples of this would be FSO tank inspections to comply with ABS regulations for corrosion prevention, pipeline pigging, and platform structure cleaning and painting.

2.18.3 Emergency Management

While incident prevention measures take priority over mitigation measures, it is COPCL Policy to have emergency response plans in place to mitigate potential impacts and prevent escalation of any incident which may occur during operations in Block A.

COPCL will prepare an Emergency Response Plan (ERP) for Block A operation. The ERP will be designed to provide the members of the Chevron Cambodia Emergency Response Organization (ERO) with the appropriate information to respond to incidents in a safe, rapid and effective manner.

In addition, COPCL will develop Site Specific ERPs to address credible and significant risks identified from site-specific risk and impact assessments. These will include an Oil Spill Response Plan, a Medical evacuation plan, and a Typhoon Evacuation plan.

COPCL will implement emergency response training and exercise programs to maintain competency of the COPCL ERO members.

2.19 Project Alternatives

2.19.1 Project Sanction

The main purpose of the proposed development project is to produce economically viable hydrocarbons from Block A using a phased development approach. The alternative is to not proceed with the proposed petroleum development project. Not proceeding with the project would fail at meeting the Royal Government of Cambodia's objective to promote and facilitate the development of the country's petroleum resources with the objective of enhancing economic growth and providing opportunities for employment and participation in petroleum operations for Cambodian nationals and companies.

2.19.2 Locations

Exact locations of all proposed platforms, FSO and wells are still to be defined. Platform A location has been selected.

Among the criteria used to select these locations are:

- The location of the reservoirs
- The location of hazards at the surface of the seabed
- The distance between the main Processing platform and the FSO
- The presence of shallow hazards
- The location allows full field development with a minimal number of platforms

Planned preliminary locations have been detailed in Section 2.4.

2.19.3 Timing of Drilling and Installation Activities

While some environmental components can exhibit some seasonal variability in sensitivity, there are no periods of significantly enhanced or reduced environmental sensitivity for drilling or installation activities. While drilling operations or installation activities can be performed during typhoons season, additional weather downtime is likely. The most probable schedule of activities is available in Section 2.2.

2.19.4 Type of Drilling Rigs

Types of drilling rigs include:

- Submersibles: towed then submerged until it sits on the bottom. Suitable to very shallow waters.
- Drillships: self propelled, anchored or dynamic positioned, normally used in deep water.
- Semisubmersibles: towed or self propelled, anchored or Dynamic Positioned, normally used in deep water.
- Jack up Rigs: towed to location, legs are lowerd to the sea floor while rig is raised into the air, limited to water depth of 600 feet or less.
- Tender Assist Drilling (TAD) Rigs: towed to location, barge is anchored next to platform, drilling equipment is placed on the platform, support equipment remains on the barge.
- Platform Rigs: brought to location on a boat, assembled onto the platform, no boat or barge required to be on location while drilling.

The project plans on using rigs that are currently under long term contract for Chevron Thailand. These are jack ups and tender assist drilling rigs. They are anchored installations. These rigs are suitable to the water depths and the metocean conditions prevailing in the Gulf Of Thailand. It is likely that a tender assist rig will be used for drilling activities at the first platform (Platform A).

2.19.5 Well Design

There were two alternatives in terms of well design:

- Standard well design

- Slim hole well design

The slim hole well design has been validated as the principal well design in the Gulf Of Thailand. This slim hole design meets all operational requirements while contributing to a reduction in the volume of cuttings and duration of drilling activities.

2.19.6 Type of Mud

There are three main types of drilling mud: Oil based mud (OBM), Synthetic Based Mud (SBM) and Water based mud (WBM).

While Water based mud (WBM) presents environmental advantages over the use of OBM and SBM, the bottom hole intervals will be drilled with a synthetic paraffin; non aqueous fluid (SBM/ NAF). WBM cannot be used in the deeper section of the wells as the formations are water-reactive, temperature is too hot and wellbore stability would be greatly compromised. NAF is less reactive with shales and helps to reduce torque and drag when compared with WBM. SBM are considered more environmentally friendly than OBM.

2.19.7 Management of Produced Water

There are two options related to produced water management:

- Treatment and overboard discharge;
- Reinjection.

While treatment to reduce the oil in water content followed by overboard discharge could be considered to be the cheapest option for the Cambodia Block A project, the potential environmental impact associated with this option would be considered potentially significant. Reinjecting produced water under normal conditions has minimal potential to create impacts on the environment.

It was decided that no produced water would be disposed of overboard into the sea under normal operations, and thus all produced water will be reinjected into the formation.

2.19.8 Management of Associated Gas

The alternatives for management of associated gas are as follows:

- Flaring of all associated gas;
- Use as fuel gas and gas lift and flaring of excess gas;
- Use as fuel gas and gas lift, reinjection of excess gas
- Transported to shore

There are no onshore facilities to commercially use the gas (e.g.: power plant) and the small volumes of gas that are expected do not justify developing a pipeline and an onshore facility at this time. Transporting the gas onshore is not an option.

Artificial lift is required for that project. Artificial lift will be done using a combination of gas lift and electric submersible pumps. Excess gas, if any, will be flared during Phase 1a. However, excess gas will be recorded over a period of several years and the decision to flare excess gas will be revisited once more data is available.

2.20 Decommissioning

Decommissioning of the Apsara Core Development Area facilities will be the appropriate removal and disposal of the fixed and floating offshore production equipment (including wells) when relevant.

A generic decommissioning methodology is described below. Specific removal procedures for each representative facility will be developed in detail prior to removal.

The planning, surveying and engineering of the decommissioning phase will begin prior to the end of production. It will include, but is not limited to:

- Recover data from the installation such as lift weights, as-built positions of platforms and pipelines, previous platform inspection results, notes of repairs/ modifications/additions, mud programs from drilling campaigns to assess likely contents and dispersal of drill cuttings, marine growth measurements on all substructures;
- Perform survey and inspection for each platform and subsea assembly to assess general structural condition and obtain baseline environmental information.
- Complete engineering and removal studies to allow liaison with regulatory authorities.

3. ENVIRONMENTAL SETTING

3.1 Introduction

This chapter describes the physical and ecological resources, human-use and quality-of-life values as well as the public health settings in the project's zone of influence. This provides the context over which the project can be overlaid, in order to evaluate the significance of potential impacts associated with the proposed activities in Chapter 5.

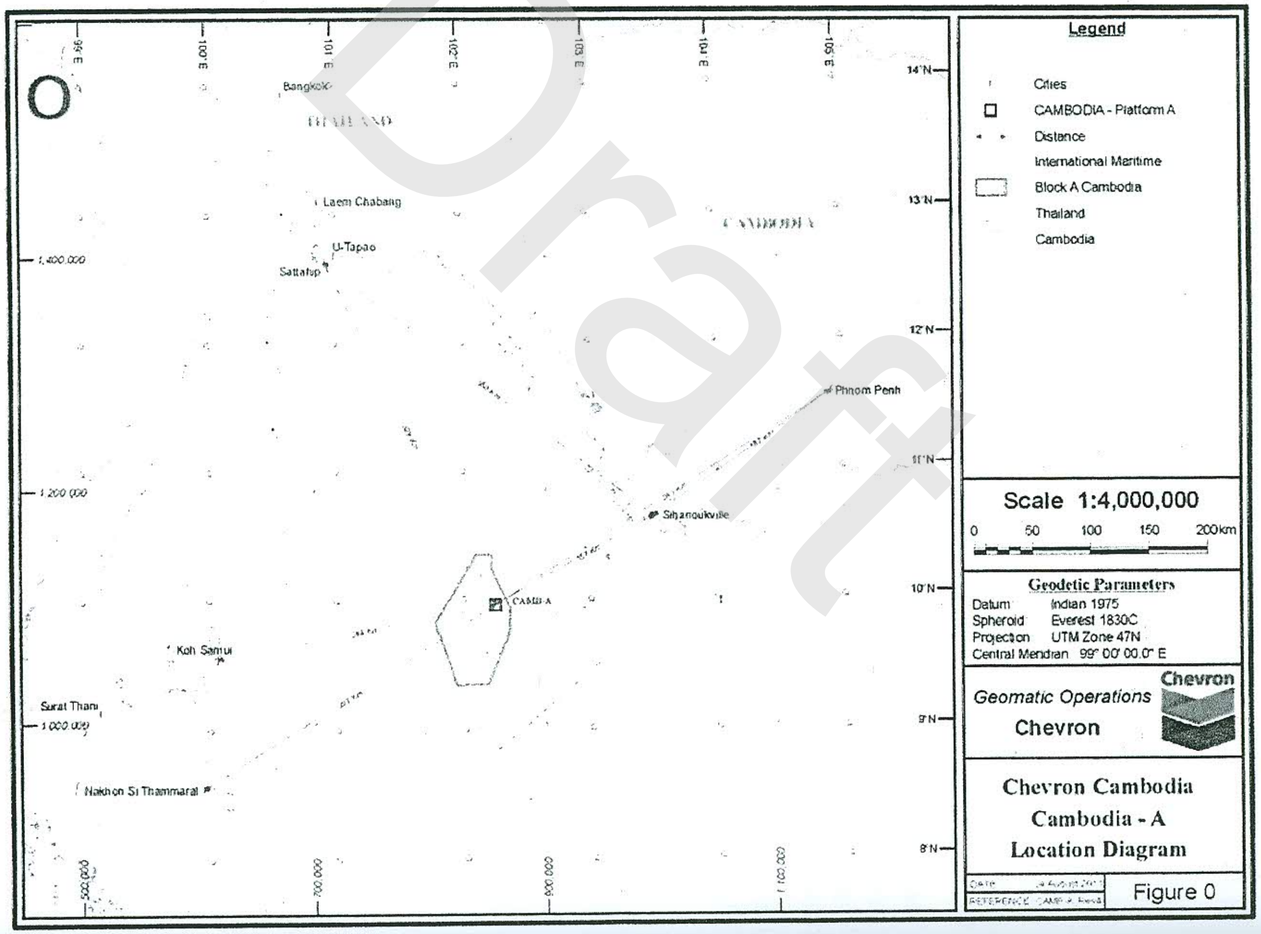
The project is located in Block A off the coast of Cambodia in the Gulf of Thailand (the Gulf), approximately 157 km from the Cambodian mainland (**Figure 3-1**). Block A covers an area of 4,709 km^2.

The Gulf is defined roughly by coastlines in the east, north and west, and in the south by a line from Cape Camau, Vietnam to Kota Baharu, Malaysia. It is 550 km across at its widest point and 835 km in length (about 350,000 km^2 in area). The Gulf has an average depth of 30 m, and is 86 m at its deepest point, in the central part of the Gulf.

The Project's zone of influence is defined as follows:

1. Physical and biological resources in the immediate vicinity of the project structures (platforms, flowlines, FSO);
2. Coastal areas, where physical and biological resources, human use and quality of life values may be impacted by the project. This includes the following four provinces:
   - Koh Kong
   - Preah Sihanouk
   - Kampot
   - Kep

Figure 3-1: Location of Block A relative to Mainland Cambodia



3.2 Data Sources

Information for the description of this environmental baseline comes from an environmental baseline survey conducted by IEM in Block A Cambodia, previous field surveys in nearby areas comparable to Block A, previous EIA reports, and publicly available literature.

Primary data sources for this EIA are as follows:

- Environmental baseline survey conducted in Block A Cambodia between October 23rd and October 29th, 2010, conducted by IEM for COPCL;
- Environmental baseline survey conducted in Block A Cambodia between April 28th and May 3rd, 2004 conducted by IEM for COPCL;
- Environmental baseline survey in G4/43 conducted during December 2003, a survey conducted by IEM for Chevron Offshore (Thailand) Ltd. (COTL);
- Three Year Environmental Monitoring Survey, Block B8/32, carried out between June 23th, 2003 and July 7th, 2003, a survey conducted by IEM for COTL.

The field surveys from Block G4/43 and B8/32 are comparable due to their proximity to Block A (both blocks are less than 50 km from Block A).

Secondary data sources come from literature, government agencies, and 3rd party independent studies, and are cited as such throughout this report.

All data sources are cited and listed in the "References" chapter.

3.3 Physical Resources

3.3.1 Climate

3.3.1.1 Meterology – General features

The main climatic features of the Gulf of Thailand are the northeast and southwest monsoons and occasional tropical cyclones. The monsoon regime generates two seasons with transitional periods between them. The characteristics of the seasons are as follows:

- **Cool/Dry season – NE monsoon:** November to February: relatively cool weather (2010 monthly average 27.7 to 29.4 °C) and relatively low rainfall (approximately 80 mm/month). Tropical cyclones are possible.
- **Hot/Dry season - Transition** – March to April: little rainfall and correspondingly hot temperatures (2010 monthly average 31.0 to 31.4 °C).
- **Hot/Wet season – SW monsoon:** May to September: overcast skies, daily light rain, interspersed with squalls, thunderstorms, and occasional torrential rains (approximately 160 mm/month). Temperature ranges from 29.1 to 32.0 °C (2010 monthly average).
- **Cool/Wet season - Transition** – October: Relatively cool weather (2010 monthly average 28.2 °C). Tropical cyclones are possible.

Monthly average temperatures in Phnom Penh and the Gulf of Thailand from 2006-2009 are shown in **Table 3-1**.

Table 3-1: Monthly Average Temperature in Phnom Penh and the Gulf of Thailand (2006-2009)

Season			NE		Trans		SW					Trans	NE		
Month			1	2	3	4	5	6	7	8	9	10	11	12	Annual Average
2006	Phnom Penh	min	23.5	24.4	24.9	25.8	25.7	25.6	25.4	25.1	25.1	24.9	24.8	22.6	24.8
		max	32.5	34.4	34.3	35.5	35	35.1	33.6	33.3	32.2	31.9	32.6	31.4	33.5
	Gulf of Thailand	min	22	23.9	24.7	24.8	24.1	25	25.8	25.2	24.4	24.2	23.8	21.7	24.1
		max	32.8	33.9	33.6	34.5	33.3	32.2	31.4	31.3	31.9	32.6	34	32.5	32.8
2007	Phnom Penh	min	23	22.7	24.7	26.3	26	26	25.5	25.2	25.5	25	23.2	22.9	24.7
		max	32	33.4	34.7	36.1	34.4	33.7	32.2	32.7	32.9	31.2	29.7	31.5	32.9
	Gulf of Thailand	min	22.4	22.9	24.7	24.6	25.4	25.3	24.7	25.4	24.8	24.6	23.1	22.5	24.2
		max	33.2	32.5	33.3	33.9	33.2	33.3	32.2	31.7	31.8	31.8	31.6	33.1	32.6
2008	Phnom Penh	min	20	21.3	21.5	23.2	23.7	23.7	23	22.9	22.3	22.8	22.3	21	22.3
		max	34.1	34.7	36.8	37.2	36	36	36.5	34.7	34.9	34	32.9	31.1	34.9
	Gulf of Thailand	min	22.2	23.1	24,6	24.8	25.1	25.2	24.7	24.8	24.5	24.6	23.4	21.7	24
		max	32.8	32.2	33	33.5	31.7	32	31.6	31.9	31.6	33	30.8	31.4	32.1
2009	Phnom Penh	min	21	23.8	25.3	25.5	25.6	25.5	25	25.4	24.9	24.9	23.7	23	24.5
		max	29.9	34	35.5	36	34.5	34.5	32.7	34.3	33	32.4	31.8	32.6	33.4
	Gulf of Thailand	min	20.2	23.4	24.4	25.3	25.5	26.2	25.4	25.3	24.7	24.2	22.7	22.3	24.1
		max	31.2	33.3	33.2	34.2	33.6	32.3	31.4	34.2	31.4	31.8	32.5	33.2	32.7

Source: Table realised with data from Japan Meteorological Agency. WMO Regional Climate Center. Monthly Data List. http://ds.data.jma.go.jp/gmd/tcc/climatview/obsmonthlist.jsp?a=1&yy=2009&mm=12&lon0=49.94999999999999&lon1=169.95&lat0=-18.75&lat1=41.25, Accessed July 2011

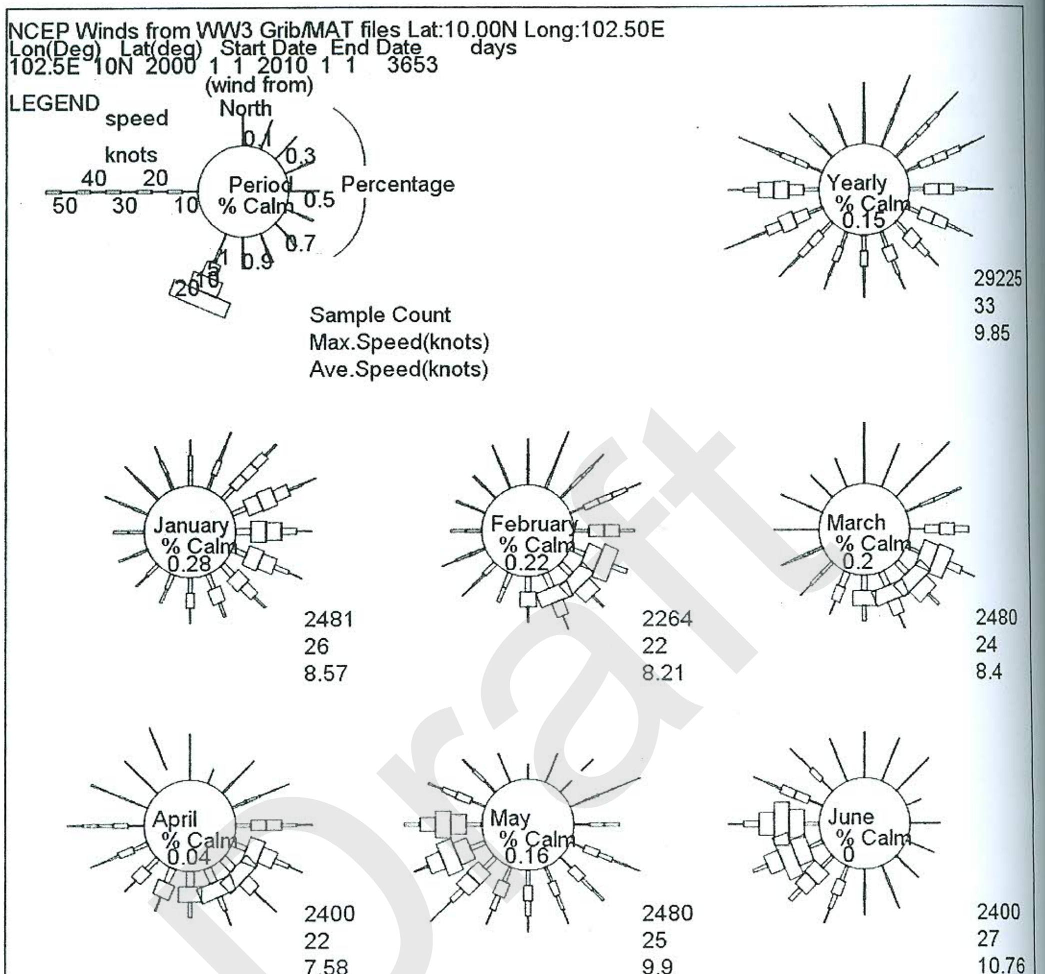
3.3.1.2 Winds

Local wind data was retrieved from the National Centres for Environmental Predictions (NCEP) Global Forecast System (GFS) model by Asia-Pacific ASA (2011). Wind data from January 2000 to January 2010 at a station in the center of the Gulf (located at 10.00N, 102.50E, approximately 17 km east of Block A) were used to generate monthly and annual wind rose distributions. Wind rose distribution is presented in **Figure 3-2** and summarized below.

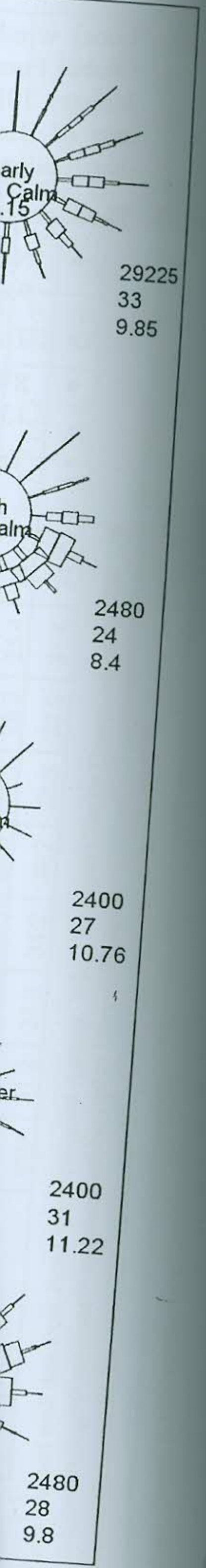
There are two wind seasons with two transitional periods between them:

- NE monsoon: November – February; prevailing northeast winds with average speeds 8.2-9.85 knots.
- Transition – March – April; prevailing southeast winds with average speeds 7.85-8.4 knots.
- SW monsoon: May – September; prevailing winds from southwest with average speeds 9.9-13.21 knots.
- Transition – October: variable wind direction with average wind speed 8.62 knots.

Figure 3-2: Wind Rose for Central Gulf



Source: Asia-Pacific Applied Sciences, 2011



3.3.1.3 *Tropical Cyclones*

Tropical cyclones affecting the Gulf of Thailand usually originate in the western North Pacific Ocean or the South China Sea. Cyclones are characterized by wind speed:

- Tropical depression: maximum sustained winds up to 33 knots (61 km/h);
- Tropical storm: maximum sustained winds between 34 to 63 knots (62 to117 km/h); and
- Typhoon/Hurricane: maximum sustained winds 64 knots and above (118 km/h and above).

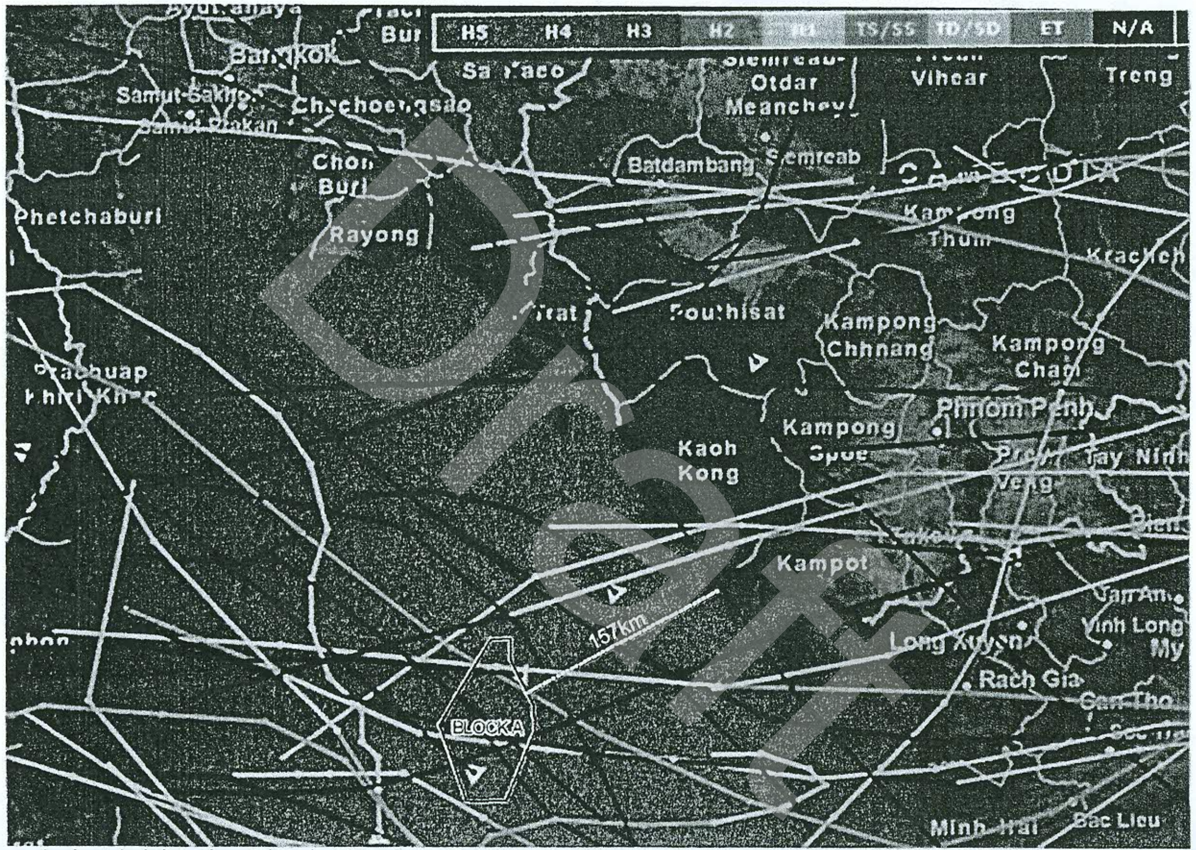
The Gulf can be affected by the three types of tropical cyclones listed above. Based on records from 1940 to 2008 from the National Oceanic and Atmospheric Administration (NOAA) Historical Hurricane Tracks, tropical cyclones in the Gulf of Thailand have a higher probability of occurrence in October and November (**Table 3-2**). **Figure 3-3** shows the paths of all typhoons in the South China Sea from 1940 to 2008.

Table 3-2: Tropical Cyclones in the Gulf of Thailand (1940 – 2008)

Month	H5	H4	H3	H2	H1	TS/SS	TD/SD	ET	NA	Total Number of Storms
January	0	0	0	0	0	0	0	0	0	0
February	0	0	0	0	0	1	0	0	0	1
March	0	0	0	0	0	0	0	0	0	0
April	0	0	0	0	0	0	0	0	1	1
May	0	0	0	0	0	0	0	0	1	1
June	0	0	0	0	0	0	0	0	0	0
July	0	0	0	0	0	0	0	0	1	1
August	0	0	0	0	0	0	0	0	0	0
September	0	0	0	0	0	0	1	0	4	3
October	1	1	0	0	2	7	1	0	6	18
November	0	1	1	2	6	6	0	0	7	23
December	1	1	1	1	0	2	1	0	0	8

Note: 41 occurences (all types of tropical cyclones) reported in 68 years
Source: National Oceanic and Atmospheric Administration, Historical Hurricane Tracks, http://csc.noaa.gov/hurricanes/#app=1834&3e3d-selectedIndex=0, Accessed June 2011
H5 - Hurricane Category 5 – Maximum Sustained Winds (MSW) >135 kts
H4 - Hurricane Category 4 – Maximum Sustained Winds (MSW) 114 – 135 kts
H3 - Hurricane Category 3 – Maximum Sustained Winds (MSW) 96 – 113 kts
H2 - Hurricane Category 2 – Maximum Sustained Winds (MSW) 83 – 95 kts
H1 - Hurricane Category 1 – Maximum Sustained Winds (MSW) 64 – 82 kts
TS/SS – Tropical/Subtropical Storm – Maximum Sustained Winds (MSW) 34 – 63 kts
TD/SD – Tropical/Subtropical Depression – Maximum Sustained Winds (MSW) <34 kts
ET - Exratropical Storm or Disturbance
NA – Unknown Type

Figure 3-3: Hurricane/Typhoon Tracks in the South China Sea, 1940 to 2008



Source: National Oceanic and Atmospheric Administration, Historical Hurricane Tracks, http://csc.noaa.gov/hurricanes/#app=1834&3e3d-selectedIndex=0, Accessed June 2011

H5 - Hurricane Category 5 – Maximum Sustained Winds (MSW) >135 kts
H4 - Hurricane Category 4 – Maximum Sustained Winds (MSW) 114 – 135 kts
H3 - Hurricane Category 3 – Maximum Sustained Winds (MSW) 96 – 113 kts
H2 - Hurricane Category 2 – Maximum Sustained Winds (MSW) 83 – 95 kts
H1 - Hurricane Category 1 – Maximum Sustained Winds (MSW) 64 – 82 kts

TS/SS – Tropical/Subtropical Storm – Maximum Sustained Winds (MSW) 34 – 63 kts
TD/SD – Tropical/Subtropical Depression – Maximum Sustained Winds (MSW) <34 kts
ET - Exratropical Storm or Disturbance
NA – Unknown Type

3.3.2 Geology

3.3.2.1 *Coastal Morphology*

The coastline of Cambodia is approximately 450 km long.

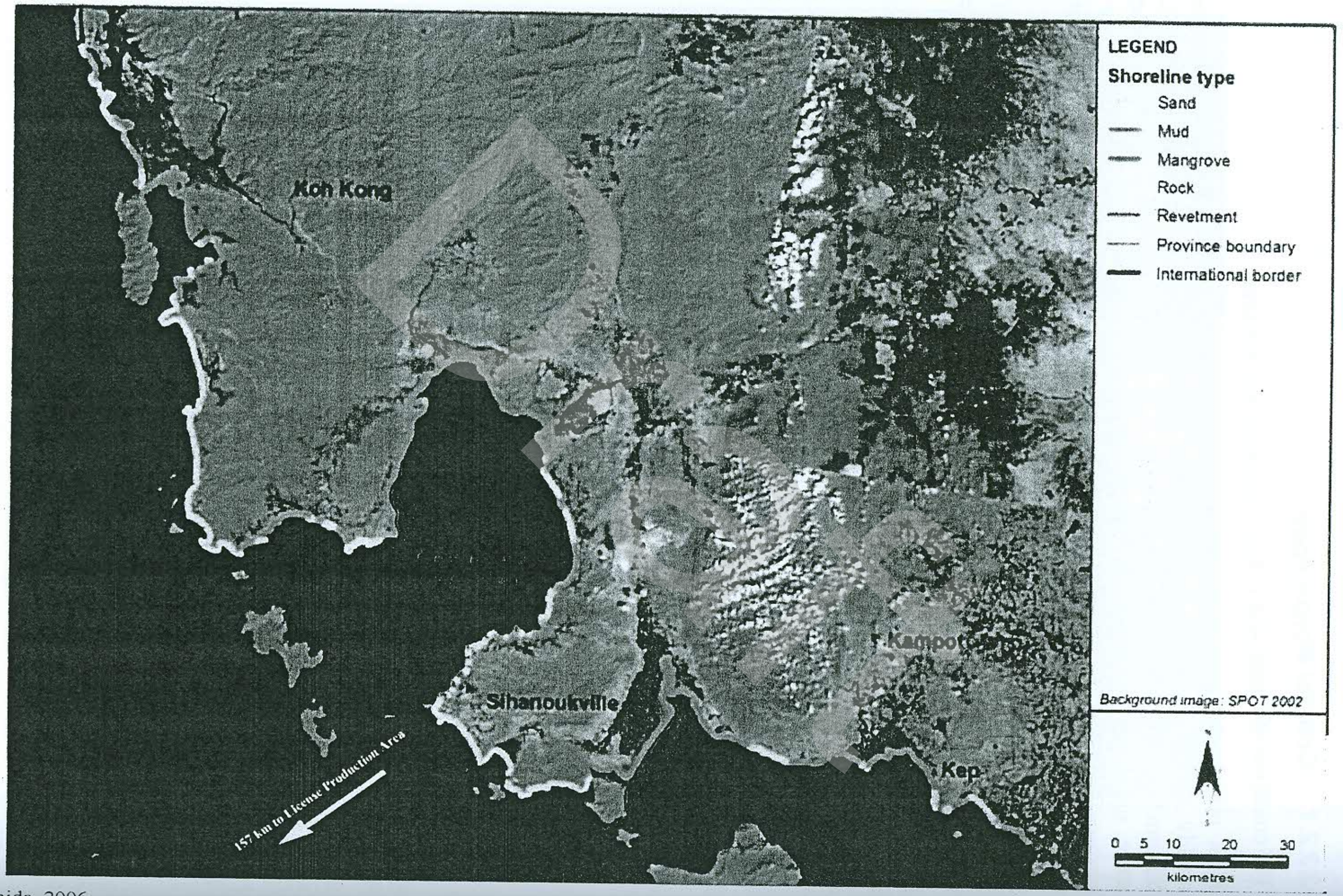
Most mainland Cambodian coastline consists of sandy beaches and rocky headlands with some muddy and mangrove-fringed areas and few reefs. The northern coastline of Cambodia (north of Sihanoukville) is primarily composed of sandy beaches, mangroves and rocky shores. Sandy beaches make up a larger proportion of the shoreline south of Sihanoukville. The area immediately surrounding Sihanoukville consists of sandy beaches interspersed with rocky outcrops and sections of mangrove.

Several rivers draining into the Gulf of Thailand form estuaries with associated wetlands (Section 3.4.2.3). Muddy substrate is often encountered in shallow waters, discharged to the Gulf by rivers and streams.

There are numerous offshore islands, where the water is clear. These islands are surrounded by areas of soft substrate, hard base rock and/or reefs (Nelson V., 1999).

A map of the coastal morphology for the Cambodian coast is shown in **Figure 3-4.**

Figure 3-4: Coastline Classification



Source: MoE and Danida, 2006

3.3.2.2 *Subsurface Geology and Tectonic Activities*

The Gulf is located in the inner portion of a geological feature known as the Sunda Shelf or Sunda Plate (**Figure 3-5).** It resembles a valley, its center shifted slightly to the south, extending over 2.2 million km^2. The Sunda Platform underlies the Java Sea, the southern part of the South China Sea, the Gulf of Thailand, and the Malacca Strait. Mesozoic and Paleozoic folded, crystalline rocks underly the shelf, and form the basement of Cenozoic sedimentary oil basins (Katili, 1970).

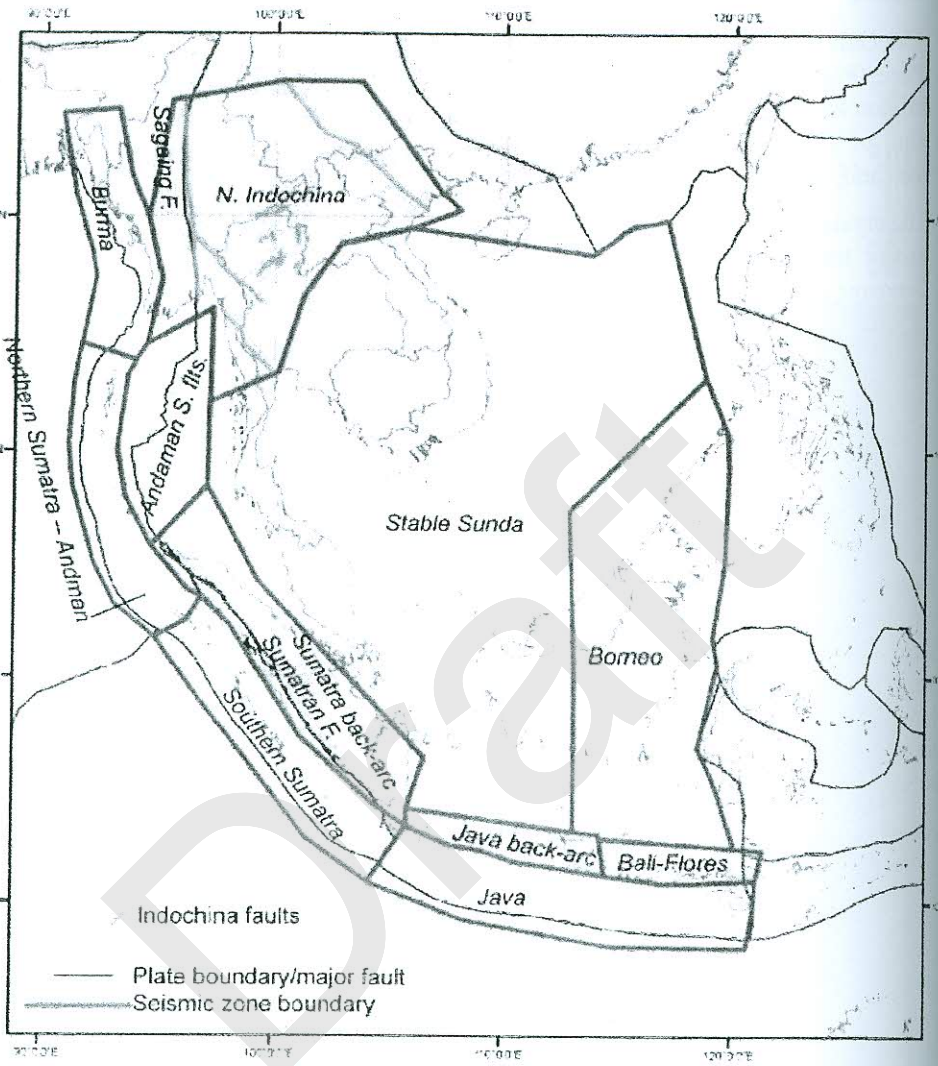
The crystalline basement rock extends out from continental Asia under much of the Sunda Shelf and, except for the areas of the early Cenozoic basins, are covered patchily by thin deposits of late Cenozoic sand and mud, a few to several hundred meters thick.

The Khmer Basin was tectonically formed as a result of extrusion in Indochina due to the collision of the Indian Plate into the Eurasian Plate. Coupling with Indian-Australian Plate movement and Philippine Sea Plate, it formed the main petroleum basins in Southeast Asia, especially in the Gulf of Thailand. The basement of the Khmer Basin consists mainly of pre-Tertiary rocks.

The margin of the Sunda plate lying in eastern Borneo has a moderate rate of earthquake activity, and geodetic evidence of tectonic deformation is reported.. The largest earthquake in the zone was the earthquake of April 19, 1923, which had a magnitude of 6.9. The Malaysian peninsula, western Borneo, and portions of eastern Thailand are located within the stable core of the Sunda plate and are characterized by low seismicity and strain rates. Within the boundary of this broad 'Stable Sunda' zone, only about 20 well-located earthquakes with magnitude greater than M5 occurred during the years 1964 to 2007. Geodetic data also indicate that strains measured within the Stable Sunda zone are low. This region, however, is situated about 300-600 km from the Sumatran faults that have historically produced earthquakes with ground motions that were felt in buildings in Singapore and Kuala Lumpur (adapted from USGS).

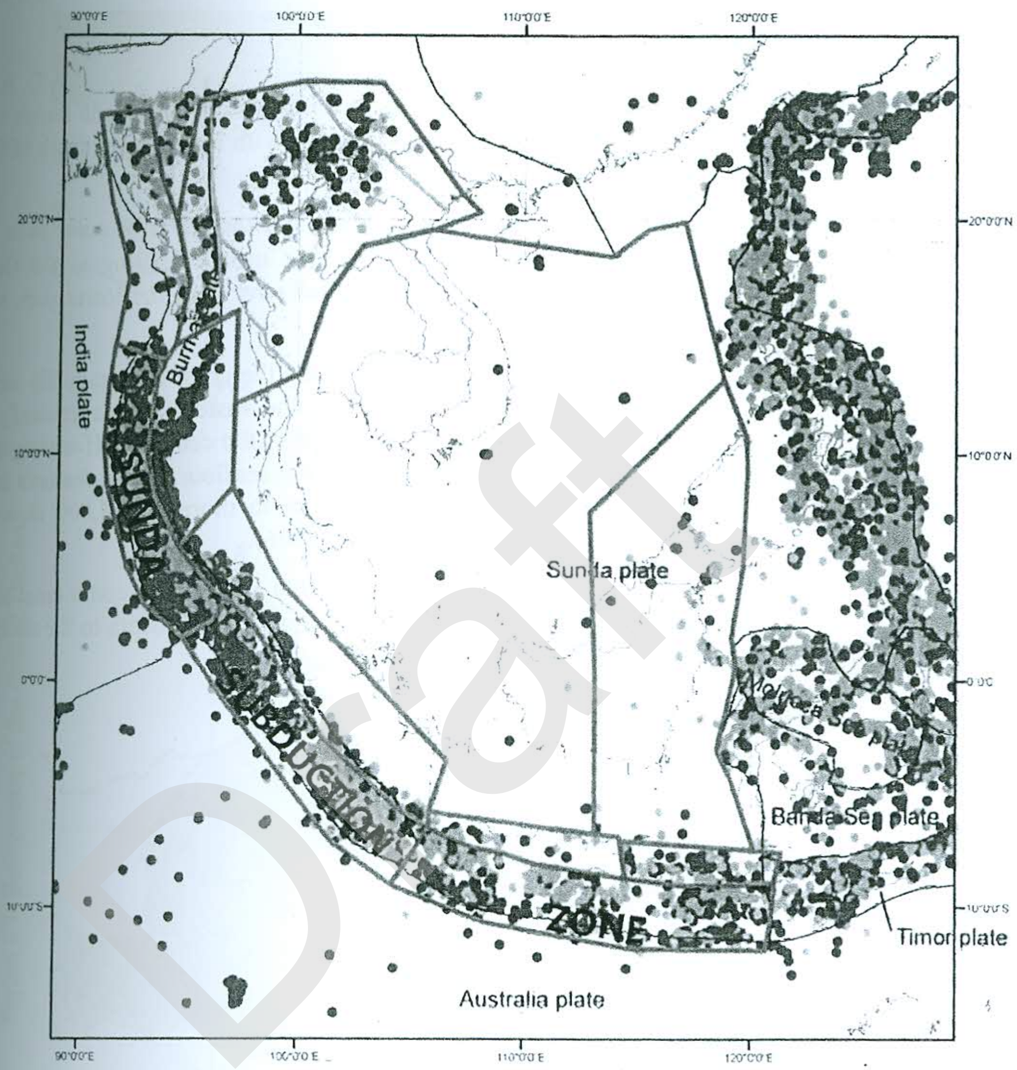
A map of earthquakes in the region is shown in **Figure 3-6**.

Figure 3-5: Sunda Shelf



Source: USGS

Figure 3-6: Map of Earthquakes with Shallow-Focus Epicentre for Period 1965-2005



- focal-depth less than 30 km
- focal-depth between 30 km and 50 km
- plate-boundary or major fault
- Seismic zone boundary

Source: USGS

3.3.3 Oceanography

3.3.3.1 Bathymetry

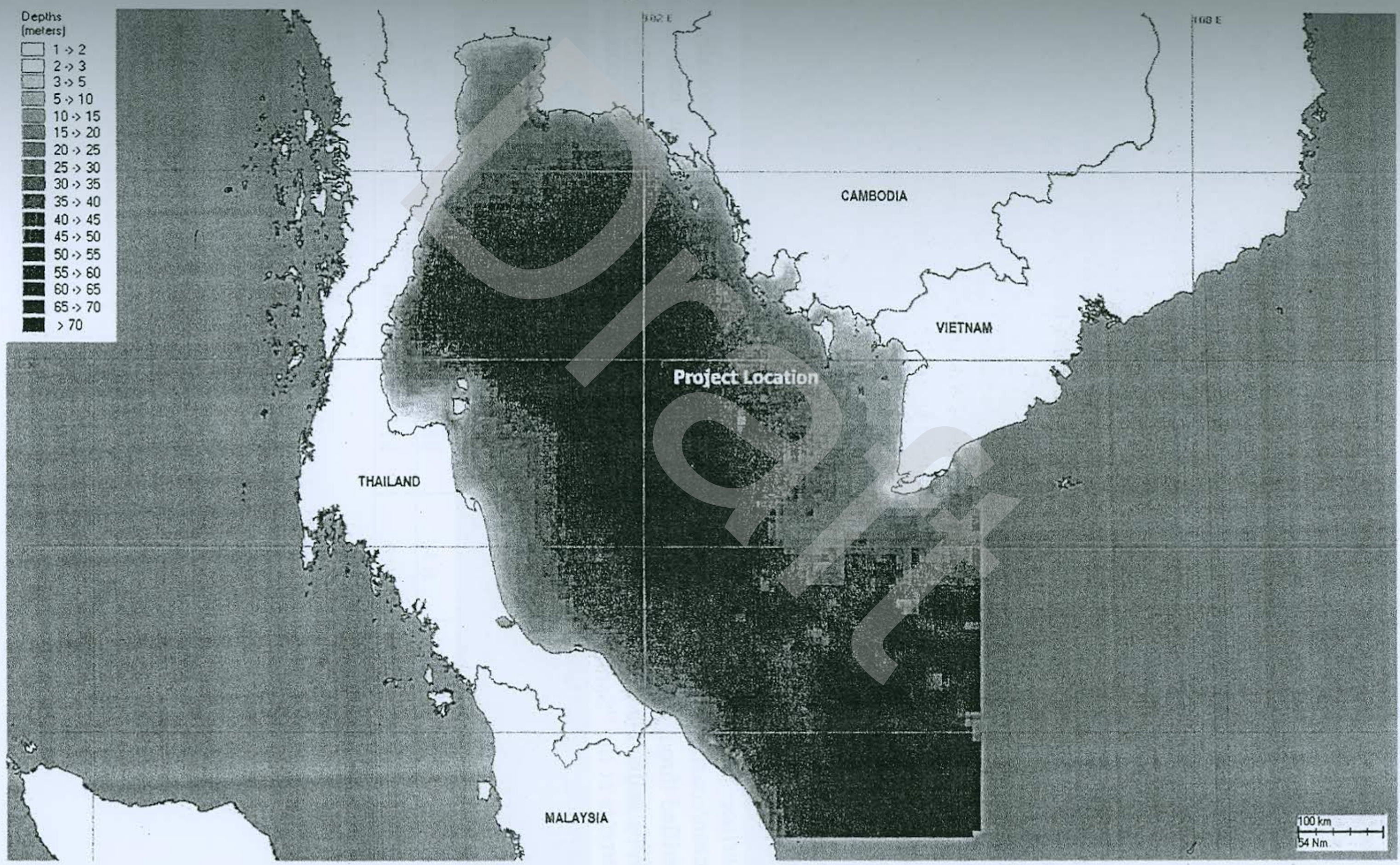
The Gulf is relatively shallow, less than 86 m at its deepest location (**Figure 3-7**). A central basin is separated from the South China Sea by two ridges forming a sill across the mouth of the Gulf with maximum water depths less than 50 m. A deeper channel with a maximum depth of 67 m divides the two ridges and connects the central basin to the open sea.

The Gulf is divided into two parts: the upper or inner, and the lower or outer parts. The upper part starts from latitude 12°30'N to the Chao Phraya River mouth (exiting to the Gulf of Thailand approximately 35 km southwest of Bangkok). It is shallower than the lower part, with an average depth of 15 m.

The topography of the Gulf shows shallow contours along the coast and gradually increases in depth towards the deepest basin in the middle (**Figure 3-7**). The eastern side is generally shallower and flatter than the rocky steep slopes of the west. The bottom of the central Gulf is irregular, with a large number of rugged (unidentified) geological features on the seafloor. These features are typically 4 m high with flat surfaces. Their width varies from 50 m to more than 4,000 m, and the distance between them ranges from 500m to 2,000 m (Wolanski, 2006).

The lower part extends to a sill from Cape Ca Mau to Kota Bahru. The continental shelf seaward of the Gulf and off the Vietnamese coast exhibits in irregular increase in depth to the shelf break at about 130 m (Emery and Niino, 1963).

Figure 3-7: Bathymetry of the Gulf of Thailand



Source: Asia-Pacific Applied Science Associates, 2011, modified IEM-2011

3.3.3.2 Currents

The Gulf is a shallow water estuary. Rain and freshwater runoff from land and rivers flow into the Gulf at the surface. High salinity, cool water flows into the Gulf from the South China Sea at the bottom near the mouth. Monsoons, tidal currents and precipitation create circulation of those waters, which influences the salinity and turbidity of the Gulf.

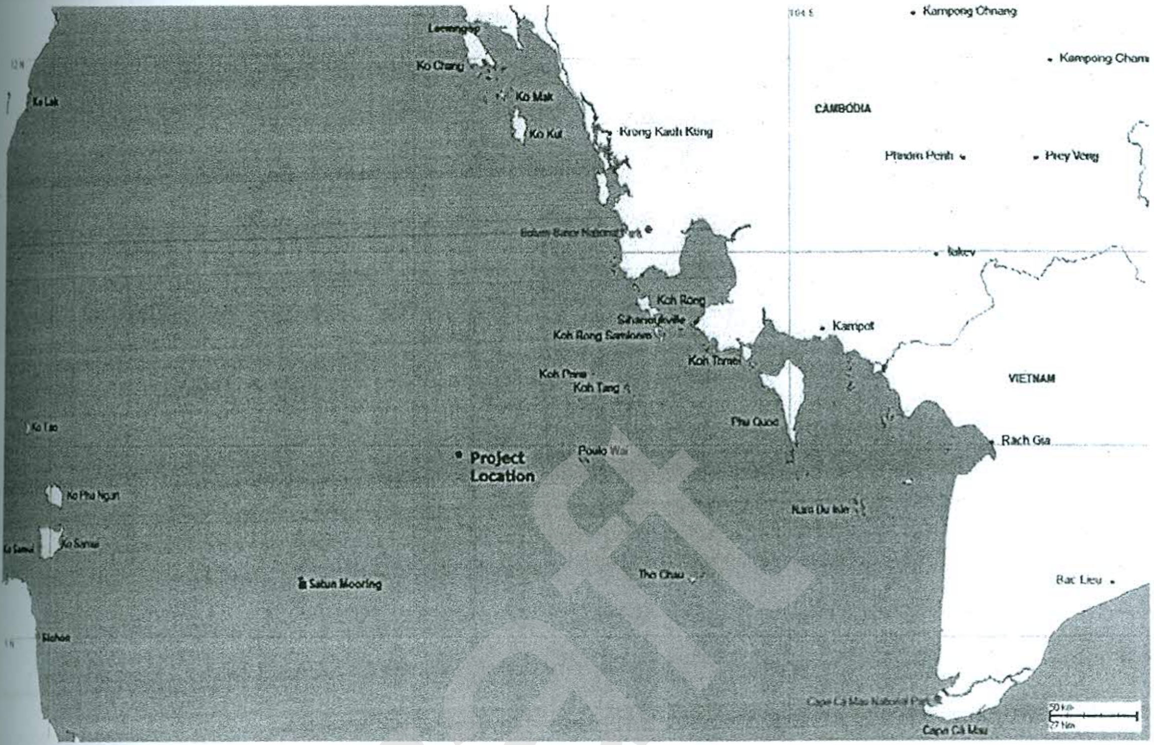
Surface currents in the Gulf are generally weak and variable, driven mostly by the light wind of the northeast and southwest monsoons. From October to May, surface currents circulate in an anti-clockwise direction with speeds of less than 0.25 m/s for 15 to 50% of the time. From June to September, these currents are reversed and flow in a clockwise direction at similar speed for 25 % of the time. Along the northeast shore of the Gulf, current speeds of 0.2 to 0.4 m/s can occur in January for 25 to 50% of the time. During the two transitional periods (March/April and October), the current is variable and weak. Particularly during the transition period (October), the northeast monsoon winds have a stronger effect on the surface currents than the other monsoon winds, causing surface currents to flow out of the Gulf (China Sea Pilot, 1987).

Chevron Offshore Thailand Ltd (COTL) measured currents in 2001 and 2002 with a current meter installed at the Benchamas Processing Platform (BPP) in the central Gulf of Thailand. Current speeds ranged from 0 to 1 knot with an average of 0.34 knots. Currents generally flowed to the northeast in the northeast monsoon with periodic shifts to the northwest. During the southwest monsoon, currents generally flowed northwest with periodic shifts to the northeast. During the transitional periods, current directions were variable. It is expected that currents in Block A are similar to that which have been observed at COTL's BPP.

Surface currents in the Gulf are shown in **Figure 3-9**.

Surface tidal currents were generated using Applied Science Associates (ASA's) advanced ocean/coastal model, HYDROMAP. The HYDROMAP model has been thoroughly tested and verified through field measurements throughout the world over the past 25 years (Isaji and Spaulding, 1984; Isaji *et al.*, 2001; Zigic *et al.*, 2003). Data from the model were compared with measured currents at the "Satun" production platform in the centre of the Gulf (location shown in **Figure 3-8**). Current speeds of the model and measured values are shown in **Table 3-3**.

Figure 3-8: Location of "Satun" Monitoring Station



Source: ASA, 2011

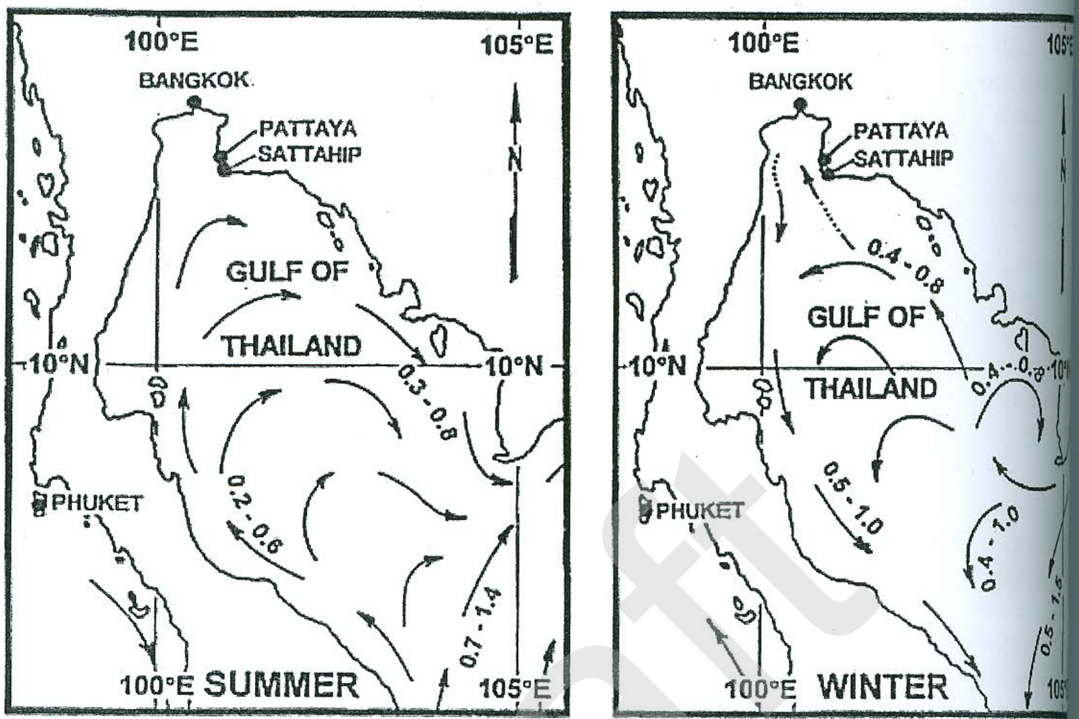
Table 3-3: Comparison between the Measured Surface and Bottom Currents at the Satun Production Platform and Model Predicted Results

Depth of current meter	Maximum current speed (m/s)		Average current speed (m/s)		Relative Mean Error (%)		Root Mean Square Error (%)	
	Measured	Predicted	Measured	Predicted	East-West	North-South	East-West	North-South
Surface	0.80	1.04	0.26	0.18	14.8	14.0	18.2	16.5
Bottom	0.88	0.65	0.21	0.16	6.9	8.6	13.6	10.7

Source: ASA, 2011

Note: Data is from 1st January to 31st May 1999.

Figure 3-9: Surface Currents in the Gulf of Thailand



Note: Currents in the Gulf of Thailand and immediately adjacent waters. Arrows indicate the mean range of current speeds in knots
Source: https://www.cnmoc.navy.mil/nmosw/thh_nc/thailand/sattahip/graphics/fig16-6.gif

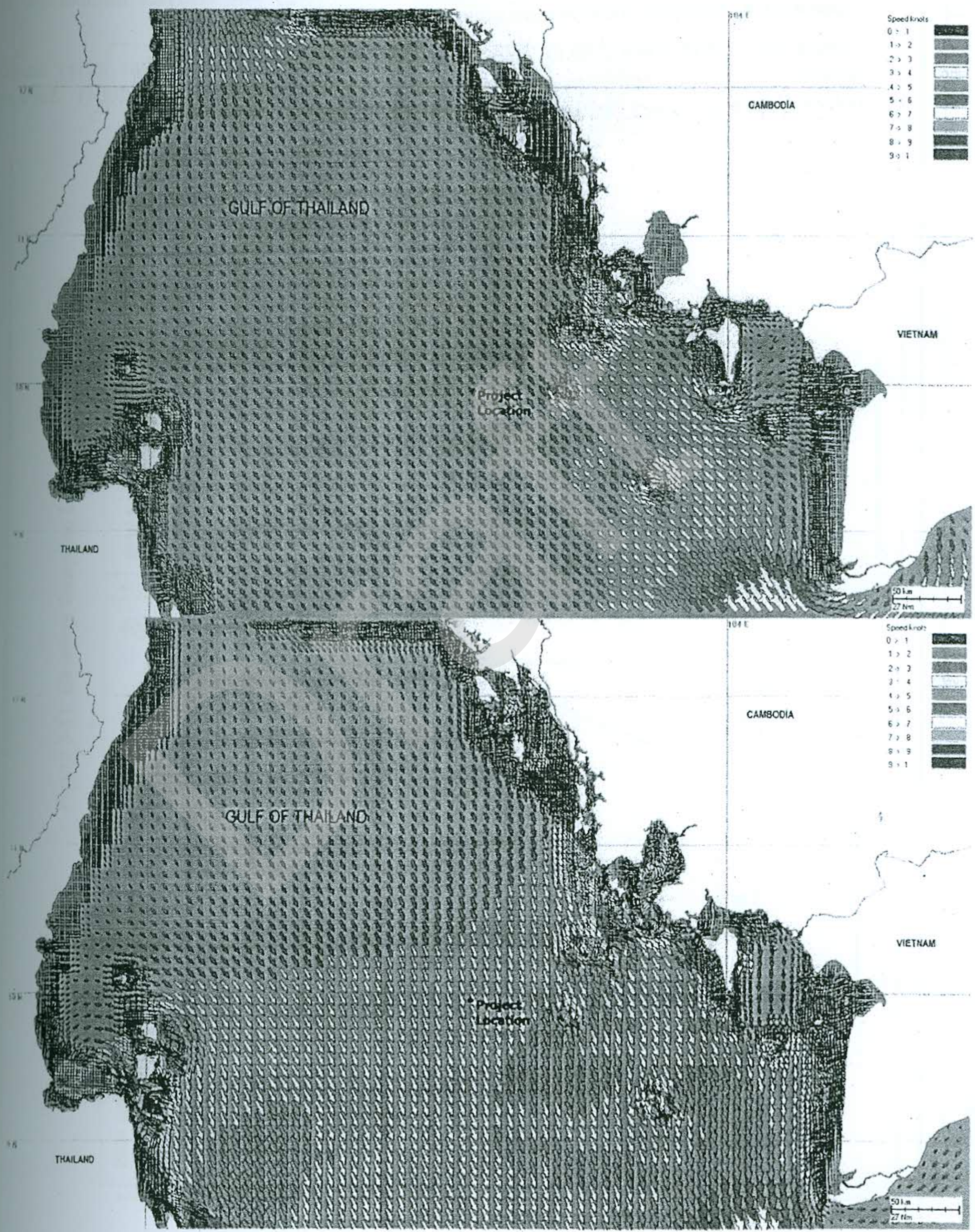
3.3.3.3 Tides

The tides of the Gulf are mixed; mainly diurnal (occasionally semi-diurnal) with inequalities in t heights and times of successive high and low waters. Diurnal tides propagate counter-clockwise a semi-diurnal tides propagate clockwise in the Gulf of Thailand (Yanagi and Takao, 1998).

The tides at the entrance to the Gulf are mixed semi-diurnal (two high tides per day), with a cl spring-neap tidal cycle.

Surface tidal currents were simulated by ASA using HYDROMAP as described in the previ section. In general, the flood and ebb tides follow along the northwest to southeast axis. The surfa water currents were shown to vary with the prevailing wind conditions and reach speeds up to 0.6 m surrounding the release sites (ASA, 2011). **Figure 3-10** shows figures of predicted flood and e surface tidal current vectors (or arrows) for the Gulf.

Figure 3-10: Predicted Flood Tide (upper image) and Ebb Tide (lower image) for the entire Gulf of Thailand



Source: ASA, 2011

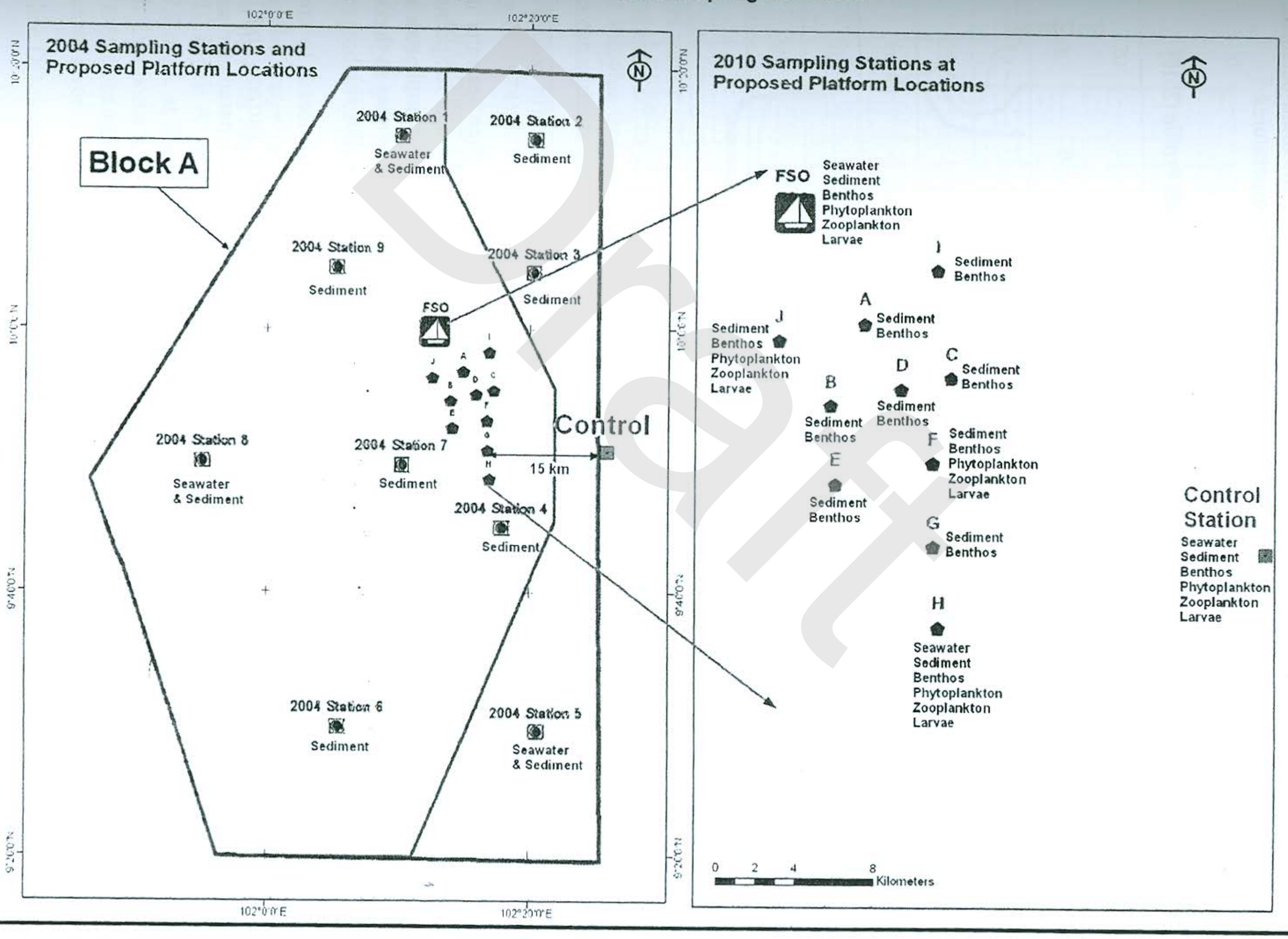
Note the spacing of the tidal vectors (or arrows) vary with the grid resolution, particularly along the coastline. Vectors colours represent change in current speeds.

3.3.4 Seawater Quality

An environmental baseline survey was conducted by IEM in Block A between October 23rd and October 29th, 2010. Details on the sampling methodology and analyses methods are provided in **Appendix 4**. Sampling locations are outlined in **Figure 3-11**.

During the period April 28th to May 3rd, 2004, an environmental baseline survey associated with previous exploration activities was conducted in Block A by IEM (IEM, 2004). Seawater quality results from both surveys in Block A are summarized below.

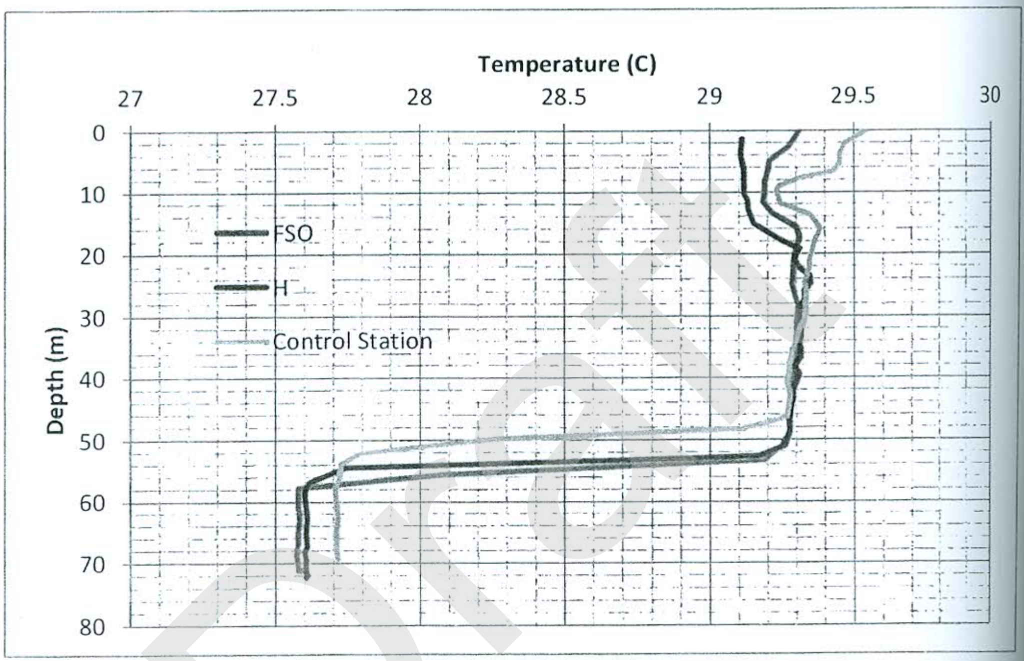
Figure 3-11: Baseline Sampling Locations



3.3.4.1 Seawater Temperature

During the 2010 Block A survey, surface seawater temperature at the stations in Block A ranged from 27.79°C to 29.54°C, and seawater temperature measured at the ocean floor ranged from 27.58°C to 27.71°C. The complete temperature-depth profile measured by the multi-parameter sonde is shown in **Figure 3-12**. Surface temperatures were higher than bottom temperatures.

Figure 3-12: Seawater Temperature Depth Profile (2010)

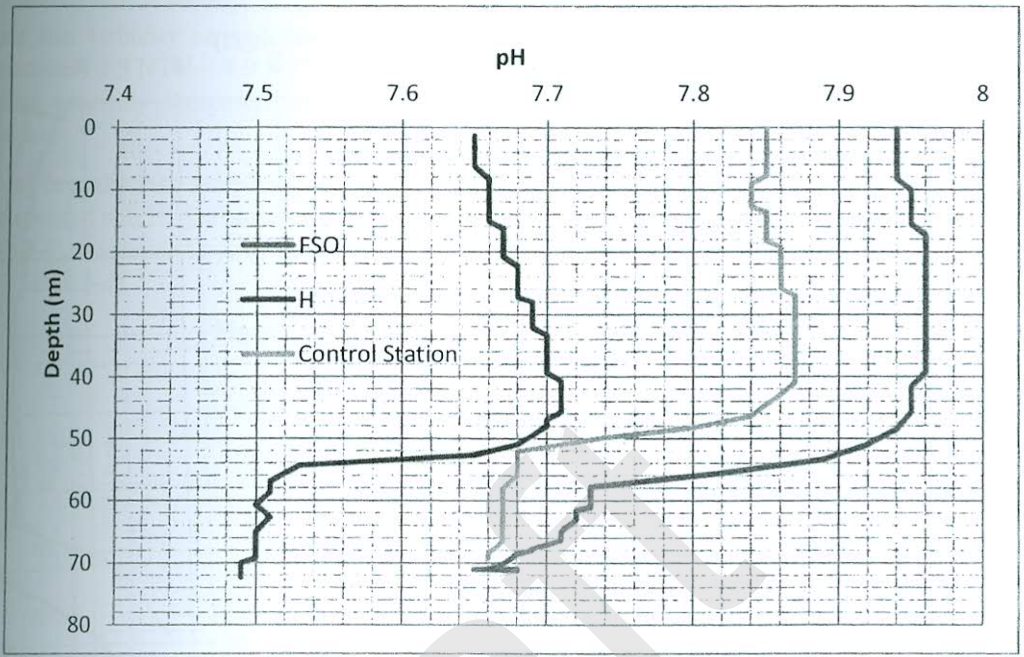


Results from the 2004 survey (IEM, 2004) were similar, with surface seawater temperature at the stations in Block A ranging from 30.8°C to 31.0°C; and bottom seawater temperatures ranging from 27.8°C to 29.4°C. The median surface and bottom temperatures of all sample stations in the Block were 30.9°C and 28.1°C, respectively. This trend is similar to other studies in the central Gulf where there is no definite thermocline (IEM 1995, 1997, 1998, 2001, 2003a, 2003b).

3.3.4.2 pH

The 2010 Block A survey found pH ranging from 7.65 to 7.94 at the surface, and 7.49 to 7.67 at the ocean floor. The complete pH-depth profile measured by the muti-parameter sonde is shown in **Figure 3-13**.

Figure 3-13: Seawater pH Depth Profile (2010)



In the 2004 survey (IEM, 2004), the pH of seawater was slightly higher, ranging from 8.17 to 8.21 at the surface and 8.09 to 8.20 at the bottom. A potential cause for this difference is the time of year at which the samples were taken. It is not uncommon to see slight seasonal fluctuations in pH due to shifts in ocean currents and climate patterns.

These measured pH values are considered to be within the range of normal seawater (7.4 to 8.3) (Goldberg E., 1974).

3.3.4.3 Dissolved Oxygen

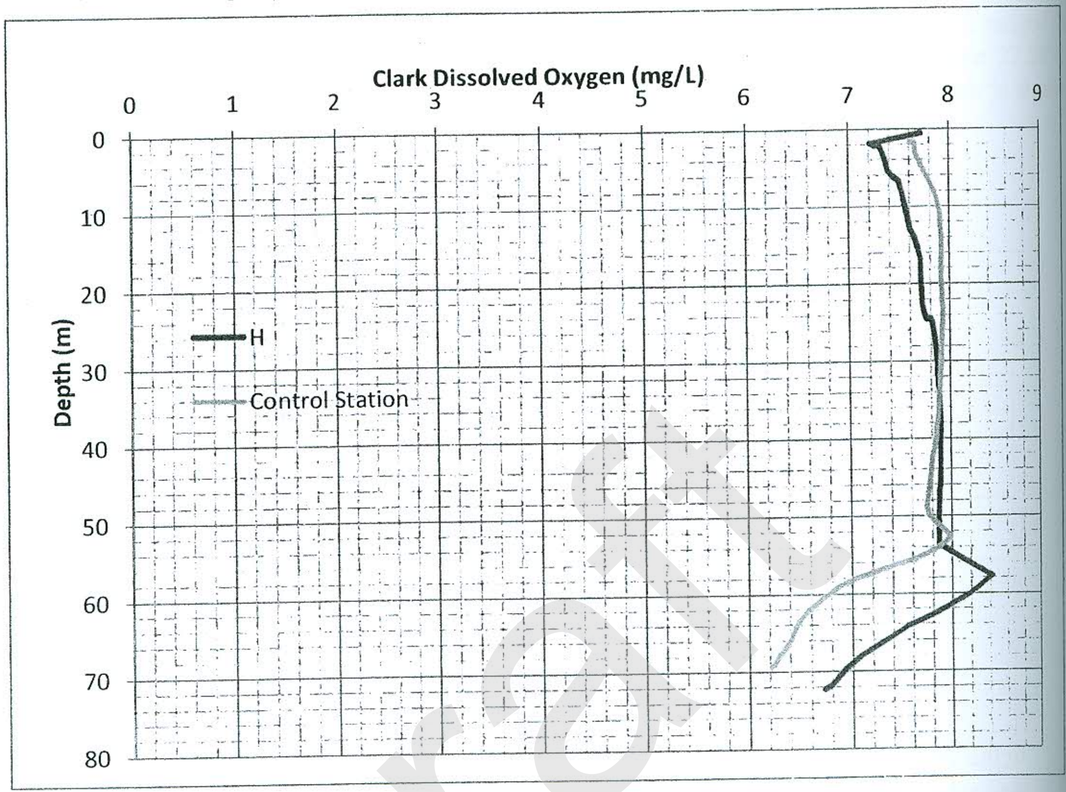
Dissolved oxygen analysis measures the amount of gaseous oxygen (O_2) dissolved in an aqueous solution. Oxygen gets into water by diffusion from the surrounding air, by aeration (rapid movement), and as a byproduct of photosynthesis. Adequate dissolved oxygen is necessary for good water quality.

The amount of dissolved oxygen in water varies considerably according to the types of life forms present in the water (and therefore the amount of photosynthesis and/or respiration present), in addition to the water temperature and pressure.

In the 2010 Block A survey, the measured dissolved oxygen (DO) ranged from approximately 7.2 mg/L to 7.7 mg/L at the surface, and from 6.2 – 6.7 mg/L at the ocean floor. DO decreased slightly with depth. Cambodia's coastal water standards are 2-7.5 mg/L DO. An attempt was made to obtain a dissolved oxygen sample at the proposed FSO Station but the results obtained were invalid, likely due to a DO sensor error.

The complete DO-depth profile measured by the multi-parameter sonde is shown in **Figure 3-14**.

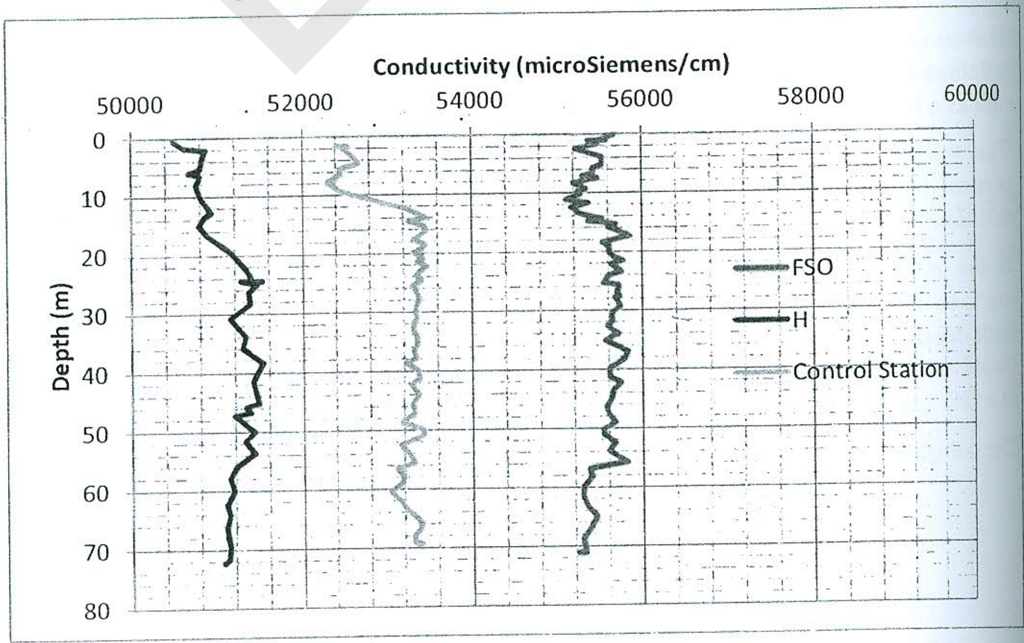
Figure 3-14: Seawater Dissolved Oxygen Depth Profile (2010)

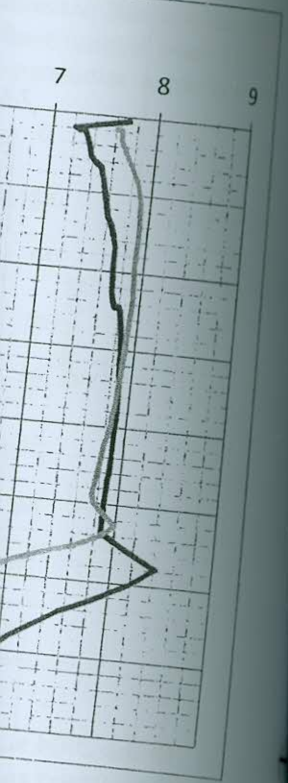


3.3.4.4 Conductivity

In the 2010 Block A survey, conductivity ranged from approximately 50,500 µS/cm to 55,700 µS/cm at the surface, and from approximately 51,100 µS/cm to 55,200 µS/cm at the ocean floor. The complete conductivity depth profile measured by the muti-parameter sonde is shown in **Figure 3-15**.

Figure 3-15: Seawater Conductivity Depth Profile (2010)





3.3.4.5 *Turbidity*

In the 2010 Block A survey, complete turbidity-depth profile measured by the multi-parameter sonde indicate that turbidity ranged from approximately 3 NTU to 5.7 NTU at the surface, and from approximately 3.9 NTU – 4.9 NTU at the ocean floor. The complete data set is shown in **Figure 3-16**. Turbidity generally increased near the bottom at all stations, which could be due to sediment disturbance.

Water at three discrete sampling stations also indicate that the water was clear with low turbidity and low suspended solids. Turbidity measured at three depths at the sampling stations was below 1 NTU (**Table 3-4**). Suspended solids measured at three depths at the sampling stations varied from <2 to 6 mg/L (**Table 3-4**).

Figure 3-16: Seawater Turbidity Depth Profile (2010)

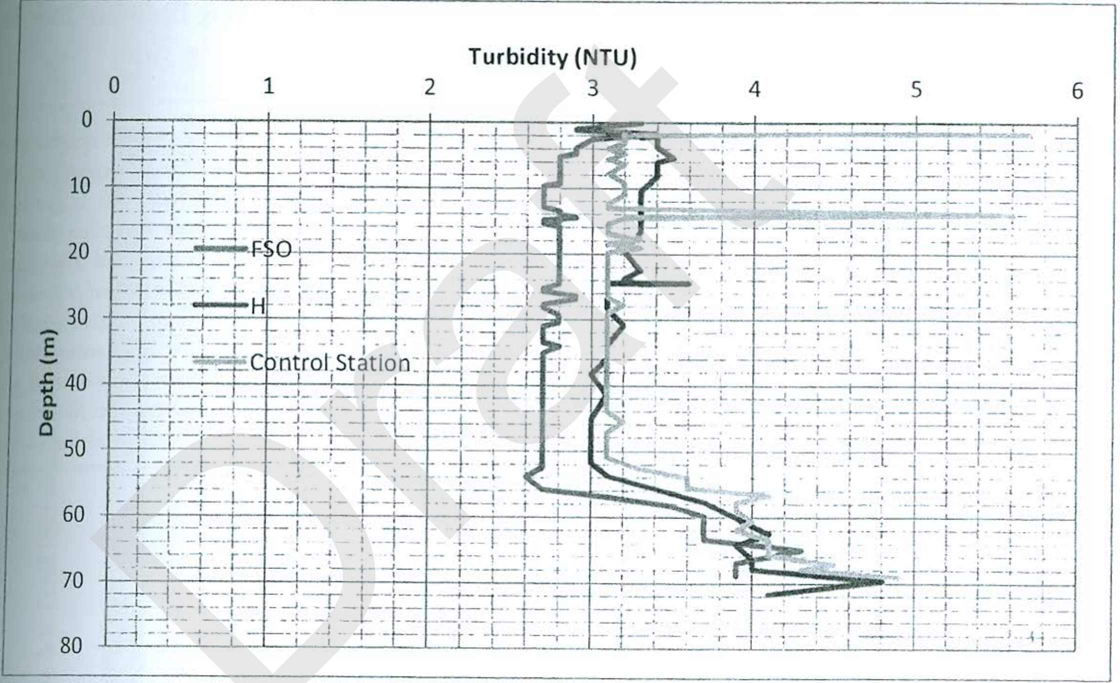


Table 3-4: Seawater Suspended Solids and Turbidity Sampling Results

Location	Depth	Turbidity (NTU)	Suspended Solids (mg/L)
FSO (proposed FSO location)	Surface	<1	4
	20 m	<1	6
	Bottom	<1	<2
H	Surface	<1	6
	DUP 1*	<1	2
	20 m	<1	6
	DUP 2**	<1	3
	Bottom	<1	3
Control	Surface	<1	3
	20 m	<1	4
	Bottom	<1	<2
Trip Blank		<1	<2
LOR		1	2

*DUP 1 was taken at Station H at the surface
** DUP 2 was taken at Station H at a depth of 20 meters

3.3.4.6 *Hydrocarbons in Seawater*

Hydrocarbons enter the marine environment by natural (e.g., diagenesis, seepage) and anthropogenic processes (e.g., oil waste, combustion) (Mille et al, 2007). The origin of hydrocarbons found in the marine environment can therefore be from multiple sources.

In the 2010 survey, samples were collected and analyzed for total hydrocarbons (THC). All sample results were below analytical detection levels. Results of total hydrocarbons in seawater for this survey are presented in **Table 3-5**.

In the 2004 survey (IEM, 2004), total hydrocarbons (THC) were measured by ultraviolet fluorescence (UVF) and reported as crude oil equivalents. Similar to the results in the 2010 survey, all sample results were below analytical detection limits for THCs.

The results from both surveys in Block A were similar to results previously found in the central Gulf in Block B8/32 in June 2003 (IEM 2003a) and in Block G4/43 during December 2003 (IEM 2003b). The levels found are typical of uncontaminated offshore waters.

Below detection levels *mean that they are below the detection limit achievable by the equipment and/or analysis used. In analytical chemistry, the detection limit is the lowest quantity of a substance that can be distinguished from the absence of that substance (a blank value). Generally this is due to either instrument detection limit or analytical method detection limit. "Instrument detection limits" exist because most analytical instruments produce a signal even when a "blank" is analyzed. Therefore there is some background "noise" at low detection levels which may not be due to the actual presence of the measured substance. For "method detection limits", many times there is more to the analytical method than just doing a reaction or submitting it to direct analysis. For example, for TPH measurement, the sample is extracted with organic solvent. The sample may also be diluted or concentrated prior to analysis on an instrument. Additional steps in an analysis add additional opportunities for error. Since detection limits are defined in terms of error, this will naturally increase the measured detection limit.*

Table 3-5: Total Hydrocarbons in Seawater of Block A (2010)

	Units	LOR	Sample Location											
			FSO-S	FSO-20	FSO-B	H-S	H-20 m	H-B	CTRL-S	CTRL-20	CTRL-B	DUP 1	DUP 2	TRIP BLANK
Aggregate Organics														
Oil & Grease	mg/L	5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Total Organic Carbon	mg/L	5	5	5	<5	5	<5	<5	5	<5	<5	5	5	<5
Total Hydrocarbons (THC)														
C6 - C9 Fraction	µg/L	20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20
C10 - C14 Fraction	µg/L	50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50
C15 - C28 Fraction	µg/L	100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
C29 - C36 Fraction	µg/L	50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50
TPH(Volatile)/BTEX Surrogate														
Dibromofluoromethane	%		95.3	102	104	97.7	101	103	94.4	103	105	93.4	103	106
Toluene-D8	%		99.5	100	101	99.4	101	102	99.8	101	101	99.7	100	102
4-Bromofluorobenzene	%		93	92.9	92.9	93	93.3	92.5	91.1	92.9	93.6	87.8	94.5	93.6

LOR = Limit of Reporting
S = Surface, 20 = 20 m depth, B = Bottom, CTRL = Control Station, DUP = Duplicate Sample
*DUP 1 was taken at Station H at the surface
** DUP 2 was taken at Station H at a depth of 20 meters

3.3.4.7 Heavy Metals in Seawater

Metals are introduced into aquatic environments through natural processes (e.g., weathering of soil and rocks) and human activities (e.g., mining) (Laws, 2000). Some metals are essential micronutrients (e.g., Mn, Fe, Cu and Zn). However, metals may be dangerous to health or to the environment at high concentrations (Laws, 2000). Therefore it is important to measure their concentrations to establish a baseline which can be used to monitor whether project operations are releasing potentially harmful levels of heavy metals.

In the 2010 survey, no unusual concentrations of any of the metals measured were detected; the metal concentrations in seawater were below detection limits at every station. Results of the heavy metals in seawater for this survey are presented in **Table 3-6**.

Some metals analyzed (Arsenic, Cadmium, Copper, Nickel, Zinc) had limits of reporting (LOR) that were slightly higher than the cited regulatory limits for those metals. IEM's long history of measurement in both Block A and throughout the Gulf of Thailand has repeatedly shown these metals to be below said standards in all previous surveys.

In the 2004 survey (IEM, 2004), no unusual concentrations of any of the metals measured were detected at any station. The metal concentrations in seawater were very low to undetectable and significantly less than the USEPA Water Quality Criteria (WQC) for Toxic Priority Pollutants and the Marine Water Quality Criteria for the Asean Region for aquatic life protection. The results were also comparable to seawater data collected from other surveys in the central Gulf (IEM 2003a, IEM 2003b).

Iron

Iron concentrations in seawater from all locations were less than the detection limit (LOR = 0.5 mg/L). Iron concentrations in all samples met the Cambodia Water Quality Standard for Public Health Protection (<0.5 mg/L).

Mercury

Mercury concentrations in seawater from all locations and control station were less than the detection limit (LOR = 0.5 µg/L). Mercury concentrations in all samples met the Cambodia Water Quality Standard for Public Health Protection (<0.5 µg/L) and the USEPA Water Quality Criteria (WQC) for Toxic Priority Pollutants (1.8 µg/L).

Arsenic

Arsenic concentrations in seawater from all locations were less than the detection limit (LOR = 10 µg/L). Cambodia Water Quality Standard for Public Health Protection is 10 µg/L, and USEPA Water Quality Criteria (WQC) for Toxic Priority Pollutants is 69 µg/L.

Barium

Barium concentrations in seawater from all locations were less than the detection limit (LOR = µg/L). These concentrations met the limit specified in USEPA Water Quality Criteria (WQC) for Non-Priority Pollutants of 1,000 µg/L. No limit for barium is specified in the Cambodia Water Quality Standard for Public Health Protection.

Cadmium

Cadmium concentrations in seawater from all locations were less than the detection limit (LOR = µg/L). The limit specified in USEPA Water Quality Criteria (WQC) for Toxic Priority Pollutants is 8.8 µg/L, and Cambodia Water Quality Standard for Public Health Protection is 1 µg/L.

Chromium

Chromium concentrations in seawater from all locations were less than the detection limit (LOR = 10 µg/L). These concentrations met the limit specified in Cambodia Water Quality Standard for Public Health Protection (Chromium VI 50 µg/L), and USEPA Water Quality Criteria (WQC) for Toxic Priority Pollutants (50 µg/L).

Copper

Copper concentrations in seawater from all locations were less than the detection limit (LOR = 10 µg/L). No Cambodia Water Quality Standard for Public Health Protection is specified for copper. However, the limit specified in the USEPA Water Quality Criteria (WQC) for Toxic Priority Pollutants is 3.1 µg/L.

Lead

Lead concentrations in seawater from all locations were less than the detection limit (LOR = 10 µg/L). Lead concentrations in all samples met the Cambodia Water Quality Standard for Public Health Protection (<10 µg/L). The limit specified in USEPA Water Quality Criteria (WQC) for Toxic Priority Pollutants is 8.1 µg/L.

Manganese

Manganese concentrations in seawater from all locations were less than the detection limit (LOR = 0.5 mg/L). There is no limit specified in the Cambodia Water Quality Standard for Public Health Protection, or USEPA Water Quality Criteria (WQC) for Toxic Priority Pollutants.

Nickel

Nickel concentrations in seawater from all locations were less than the detection limit (LOR = 10 µg/L). The limit specified in USEPA Water Quality Criteria (WQC) for Toxic Priority Pollutants is 8.2 µg/L, and there is no limit specified in the Cambodia Water Quality Standard for Public Health Protection.

Zinc

Nickel concentrations in seawater from all locations locations were less than the detection limit (LOR = 100 µg/L). The limit specified in USEPA Water Quality Criteria (WQC) for Toxic Priority Pollutants is 81 µg/L, and there is no limit specified in the Cambodia Water Quality Standard.

The heavy metal concentrations found in seawater in Block A are typical of uncontaminated offshore waters. The results are also comparable to seawater data collected from other surveys in the central Gulf (IEM 2003a, IEM 2003b, IEM 2004).

Table 3-6: Heavy Metals in Seawater of Block A (2010)

	Units	LOR	Sample Location												Standard [1]	Standard [2]
			FSO-S	FSO-20	FSO-B	H-S	H-20	H-B	CTRL-S	CTRL-20	CTRL-B	DUP 1	DUP 2	TRIP BLANK		
Metals and Major Cations (Total)																
Iron	mg/L	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	-	0.5
Mercury	µg/L	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	0.5	1.8
Arsenic	µg/L	100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	10	69
Barium	µg/L	10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	1000	
Cadmium	µg/L	10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	1	8.8
Chromium	µg/L	10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	50	50
Copper	µg/L	10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	-	3.1
Lead	µg/L	10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	10	8.1
Manganese	mg/L	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	-	-
Nickel	µg/L	10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	-	8.2
Zinc	µg/L	100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	-	81

LOR = Limit of Reporting
S = Surface, 20 = 20 m depth, B = Bottom, CTRL = Control Station, DUP = Duplicate Sample
*DUP 1 was taken at Station H at the surface
** DUP 2 was taken at Station H at a depth of 20 meters
[1] Cambodia Water Quality Standard for Public Health Protection
[2] USEPA Water Quality Criteria (WQC)

3.3.5 Sediment Quality

Sediments form a natural buffer and filter system in the material cycles in water. In addition to seawater analysis, sediment analysis is important to evaluate the quality of the ecosystem in a body of water (Stonkhorst et al, 2004). Compared to water testing, sediment testing reflects the long-term ecosystem quality independent of current inputs. Sediment tests are a better basis for fundamental comparisons with other (similar) waters. Sediments, both suspended and bottom sediments, form a reservoir for many pollutants. Pollutants in sediments can thus be used as a trace for substances with low solubility and low degree of degradability (Berlin Digital Environmental Atlas, 1993).

A survey was conducted by IEM in Block A Cambodia between October 23rd and October 29th, 2010, simultaneously with the seawater quality sampling. Details on the sampling methodology and analyses methods are provided in **Appendix 4**.

Previously, sediment samples were collected in Block A during the 2004 survey (IEM, 2004) and analyzed. Sediment quality results from both surveys are summarized below.

3.3.5.1 Particle Size Distribution

In the 2010 survey, the sediments in Block A were found to be fairly uniform. The main composition of bottom sediments is clay, sandy clay, and silty clay. The sediment composition of the 10 samples consisted of 19 – 23% clay (average 21.1%), 65 – 73% silt (average 68.2%), 7 – 13% sand (average 10.5%), and 0 – 1 % gravel (average 0.2%). The median particle size diameter (D50) ranged from 0.016 to 0.020 mm, with an average of 0.018 mm. Detailed results of particle size distribution are shown in the **Appendix 5**.

The 2004 survey (IEM, 2004) found that the sediments in Block A are uniform. The main composition of bottom sediments is clay, sandy clay, and silty clay. The seabed is underlain by very stiff, dark greenish-gray silty clay with occasionally interbedded with silt-sand laminations. Sediment samples had a high proportion of fine mud size fraction at each of the sites surveyed. The particle sizes found ranged from 1.4 μm to 0.7 mm.

The particle size distribution results are similar to those found in other central Gulf surveys in B8/32 (IEM 2003a) and G4/43 (IEM 2003b). These previous surveys took place at similar depth ranges to this project (between 55 and 70 m) and were located relatively close to Block A.

3.3.5.2 Hydrocarbons in Sediment

Petroleum hydrocarbons include thousands of organic compounds that differ in their properties including potential toxicity, environmental persistence and mobility (CCME, 1998).

In the 2010 survey, no samples at any of the stations had detectable levels of hydrocarbons in any of the measured carbon ranges, including $C_6 - C_9$ Fraction, $C_{10} - C_{14}$ Fraction, $C_{15} - C_{28}$ Fraction, and $C_{29} - C_{36}$ Fraction. Results are shown in **Table 3-7**.

Results from the IEM 2004 survey (IEM, 2004) of total hydrocarbons in sediments of Block A showed that sample results from all sites were below detectable levels for Total Hydrocarbons (THC) in sediment except at one station with THC of 0.86 mg/kg. These levels are typical of the central Gulf and comparable to levels that were found in recent surveys in the central Gulf in Block B8/32 and Block G4/43 (IEM 2003a, IEM 2003b).

Data from the IEM 2004 survey also indicated that volatile hydrocarbons (VH) in the carbon range of $C_6 - C_{10}$ were not detected in sediments at any of the stations in Block A. Total petroleum hydrocarbons (TPH), in the carbon ranges of $C_{10} - C_{19}$, were detected in sediment samples from 4 stations. Levels ranged from <5.0 mg/kg to 12.7 mg/kg (dry weight basis). The highest $C_{10} - C_{19}$ value in the 2004 survey is greater than previously determined in the Gulf of Thailand and thus indicates the potential presence of hydrocarbon impacts in the C_{10} to C_{19} (diesel) range. The source of the hydrocarbon is not known.

3.3.5.3 Total Organic Carbon

Total organic carbon (TOC) is an important parameter in sediments, both as an absorber of contaminants and as an indicator of organic matter (land based and plankton). Levels of TOC in sediment samples from the sample locations ranged from 0.5 to 2.7% (**Table 3-7**). In the Pattani Basin in the Gulf of Thailand, the average total organic carbon (TOC) contents was reported generally low to moderate (0.2-1.4 wt. %) (Bustin R.M. et al., 1997).

Table 3-7: Total Hydrocarbons in Sediments of Block A (2010)

	Units	LOR	Sample Location												
			A	B	C	D	E	F	G	H	I	J	FSO	CONTROL	DUPLICATE-SEDIMENT
Aggregate Organics															
Total Organic Carbon	%	0.5	0.9	0.6	1.8	2.7	0.7	1.1	2.3	0.6	1.9	0.5	1.8	1.9	0.9
Total Hydrocarbons (THC)															
C6 - C9 Fraction	mg/kg	2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
C10 - C14 Fraction	mg/kg	50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50
C15 - C28 Fraction	mg/kg	100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
C29 - C36 Fraction	mg/kg	100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
TPH(Volatile)/BTEX Surrogate															
Dibromofluoromethane	%		97.6	98.8	96.8	99.7	94.6	99.6	99.8	99	96.3	99.4	98.1	98.4	81.6
Toluene-D8	%		95.1	101	99.2	97.9	103	100	99	100	98.8	100	100	105	102
4-Bromofluorobenzene	%		97.2	101	95.8	99.4	96.4	104	85.6	96.5	96.4	101	97.5	104	87.6

LOR = Limit of Reporting

3.3.5.4 Trace Metals in Sediments

Heavy metals in sediments can be used as a trace for substances with low solubility and low degree of degradability. Heavy metals concentrations in sediments are good indicators of pollution in the overlying water column because natural deposition to sediments results in relatively stable concentrations.

The National Oceanic and Atmospheric Administration (NOAA) has developed numerical sediment quality guidelines (SQGs) as informal (i.e. non-regulatory) guidelines for use in interpreting chemical data from analyses of sediments (NOAA 1999; Long et al. 1995). These SQGs are based on data compiled from numerous studies in the United States that included sediment contaminant and biological effects information (including for marine sediments). The guidelines were developed to identify concentrations of contaminants that were associated with biological effects in laboratory, field, or modeling studies. Effects Range-Low (ERL) is the concentration equivalent to the lower 10th percentile of the compiled study data: sediment concentrations below the ERL are interpreted as being "rarely" associated with adverse effects.

In the 2010 survey, the concentrations of metals found in the sediments at the sampling stations in Block A were all below the Effects Range-Low (ERL) values. Thus, these levels of heavy metals in the sediments are not expected to be associated with adverse effects on biota. Results are presented in **Table 3-8**. In general, no unusual concentrations of metals were found at any of the stations sampled in Block A. The only exception was the high barium concentration at station A.

Mercury in sediments was found to have concentrations in a narrow range of 0.02 to 0.04 mg/kg. These levels appear to be the natural background levels in sediments of Block A and compare well with other areas in the central Gulf (IEM 2003a; IEM 2003b; IEM 2010).

Barium was found to range from 24 to 247 mg/kg. The highest value (247 mg/kg) was found at station A; this value is considerably higher than other concentrations measured in the Gulf. It is possible that the elevated barium concentration is the result of previous drilling operations in the area. Barite is virtually insoluble and thus non-toxic under most environmental conditions. No barium compounds have been designated as a toxic priority pollutant under the USEPA Clean Water Act.

Arsenic in sediments was found to have concentrations in a narrow range of 1 to 8 mg/kg. All measured concentrations are below the ERL guideline of 8.2 mg/kg. These levels compare well with other areas in the central Gulf (IEM surveys conducted in 2004 and 2006).

Nickel in sediments was found to have concentrations in a narrow range of 17 to 21 mg/kg. Most measured concentrations are below the ERL guideline of 20.9 mg/kg, with one value slightly exceeding the guideline. These levels however compare well with other areas in the central Gulf (IEM surveys conducted in 2004, 2006).

During the 2004 survey, all levels of heavy metals found in sediments in Block A were very low and comparable to other surveys in the central Gulf in B8/32 and G4/43 (IEM 2003a, IEM 2003b). No unusual concentrations of metals were found at any of the stations sampled in Block A, with the exception of barium. Mercury in sediments was found to have concentrations in a narrow range of 0.02 to 0.04 mg/kg with a median of 0.03 mg/kg (IEM, 2004). These levels appear to be the natural background levels in sediments of Block A and compare well with other areas in the central Gulf (IEM 2003a, IEM 2003b). Barium was found to range from 8.5 to 38.6 mg/kg with a median of 10.5 mg/kg (IEM, 2004). The highest value (38.6 mg/kg) was found at station 4, which is about 400 meters from COPCL's previous exploration well Kdang Ngea-1.

The concentrations of heavy metals found in sediments Block A are typical of uncontaminated offshore sediments, except for barium as noted above.

Table 3-8: Metal Concentrations in Sediments of Block A (2010)

	Units	LOR	Sample Location													
			A	B	C	D	E	F	G	H	I	J	FSO	CONTROL	DUPLICATE -SEDIMENT (STATION H)	ERL [1]
Metals and Major Cations																
Mercury	mg/kg	0.02	0.03	0.04	0.04	0.04	0.03	0.04	0.04	0.04	0.02	0.04	0.04	0.04	0.04	0.15
Arsenic	mg/kg	1	8	3	3	3	4	3	8	7	2	4	4	4	6	8.2
Barium	mg/kg	1	247	85	45	57	30	41	27	26	31	40	38	24	26	NA
Cadmium	mg/kg	0.02	0.1	0.1	0.09	0.1	0.13	0.09	0.1	0.1	0.1	0.09	0.1	0.1	0.09	1.2
Chromium	mg/kg	1	24	20	22	21	23	21	23	24	22	23	22	25	23	81
Copper	mg/kg	1	7	6	7	6	7	7	7	7	7	10	7	7	7	34
Lead	mg/kg	1	16	14	15	14	16	14	16	16	14	15	14	15	16	218
Nickel	mg/kg	1	20	17	19	17	20	18	20	20	18	20	19	21	20	20.9
Zinc	mg/kg	1	32	26	29	26	28	26	28	29	26	30	27	31	28	150

Notes: 1 ERL (Effects Range-Low) is the concentration equivalent to the lower 10th percentile of the compiled study data: sediment concentrations below the ERL are interpreted as being "rarely" associated with adverse effects

NA Not Available

3.4 Biological Resources

This section describes ecological resources that could potentially be affected by the proposed project.

There are three marine ecosystems of interest:

- Shallow coastal area: fringed by mangroves, mudflats or other wetlands (often parts of estuarine systems), is an important nursery habitat for shellfish (mollusks) and shrimps;
- Intermediate shelf area: a sub-tidal habitat for small-to medium-sized pelagic and demersal fish; and
- Deep shelf area: habitat for larger pelagic and demersal fish.

3.4.1 Marine Life

The information in the following sections is derived from the 2010 survey carried out by IEM, as well as secondary data where stated. Details on the sampling methodology and analyses methods for the 2010 survey are provided in **Appendix 4**.

3.4.1.1 General Definitions

Diversity index

Diversity indices are commonly used to assess the state of an ecosystem (e.g., as a criterion for conservation evaluation), with high diversity generally being considered a desirable property in a community or ecosystem. Shannon's diversity index (*H'*) is one of the most commonly used diversity indices.

Richness

The "species richness" is simply the number of species present in an ecosystem. Margalef's richness index provides a measure of species richness that is roughly normalized for sample size without using more complex rarefaction techniques.

Evenness

The "species evenness" is the relative abundance or proportion of individuals among the species. Pielou's evenness index (*J'*) is one mathematical method of representing the evenness of a community.

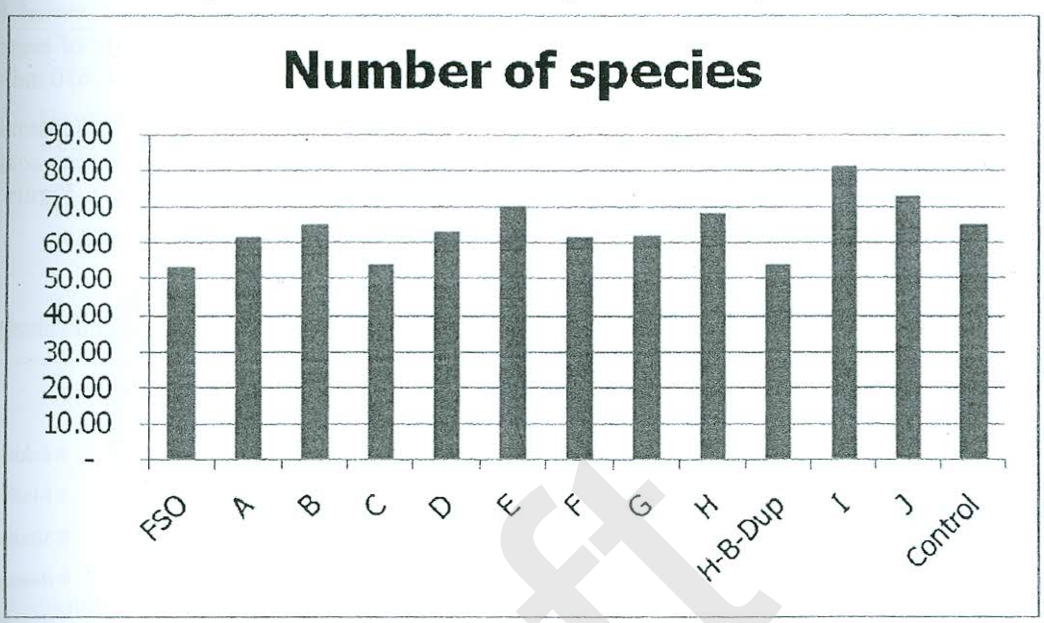
3.4.1.2 Benthos

Benthos from 10 proposed platform stations (plus one duplicate), and one proposed FSO station were collected in October 2010. In addition, a control station outside the concession area was sampled for comparison (**Figure 3-11**).

Number of Benthos Species

Identification of the benthic samples collected in 2010 determined the presence of 184 benthic species in the project area. The total number of benthos species at each station ranged between 53 – 81 species, with a mean 64±8 species per station (**Figure 3-17**). The FSO station had the lowest number of species (53 species/station). Station I had the highest number of benthos species (81 species/station). The variability in number of benthic species over the entire project area is only slightly greater than at Station H. In general, the number of benthos species in the project area is high compared to other areas in the deep basin of the Gulf of Thailand (Plathong, 2010). The complete list of benthos species is shown in **Appendix 6**.

Figure 3-17: Number of Benthos Species in the Project Area

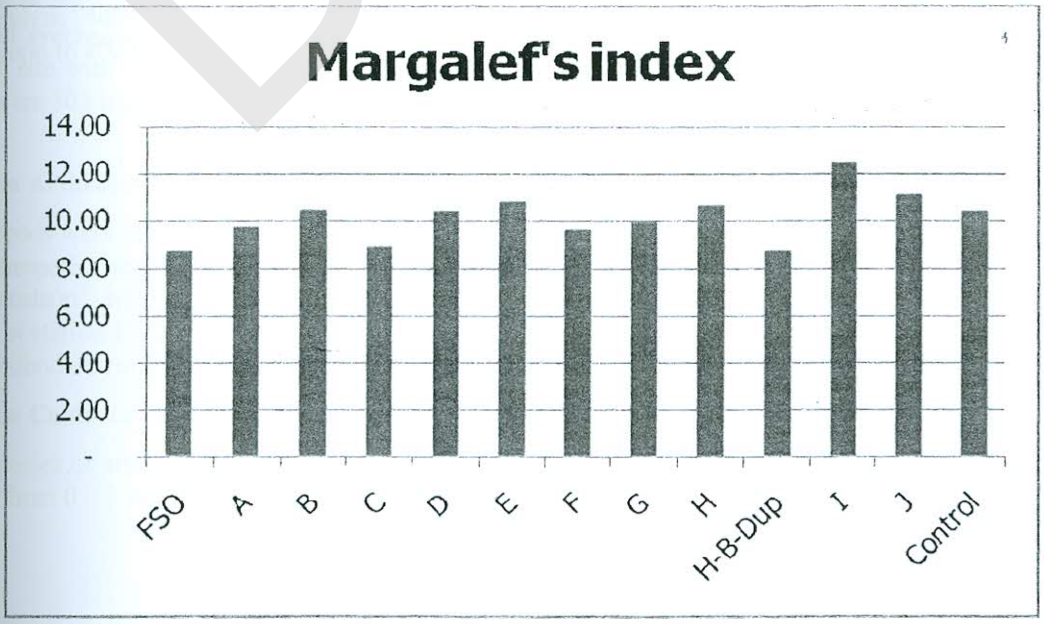


Source: 2010 Environmental Baseline Survey (EBS)

Margalef's Richnes Index

Margalef's richness index was analyzed to compare richness of species between stations sampled during the 2010 survey. The analysis shows that the Margalef's Richness Index at each station was similar for all stations and follows the presence of species at the sampling sites (**Figure 3-17** and **Figure 3-18**). The variability in benthic species richness over the entire project area is only slightly greater than at Station H.

Figure 3-18: Richness Index of Benthos in the Project Area



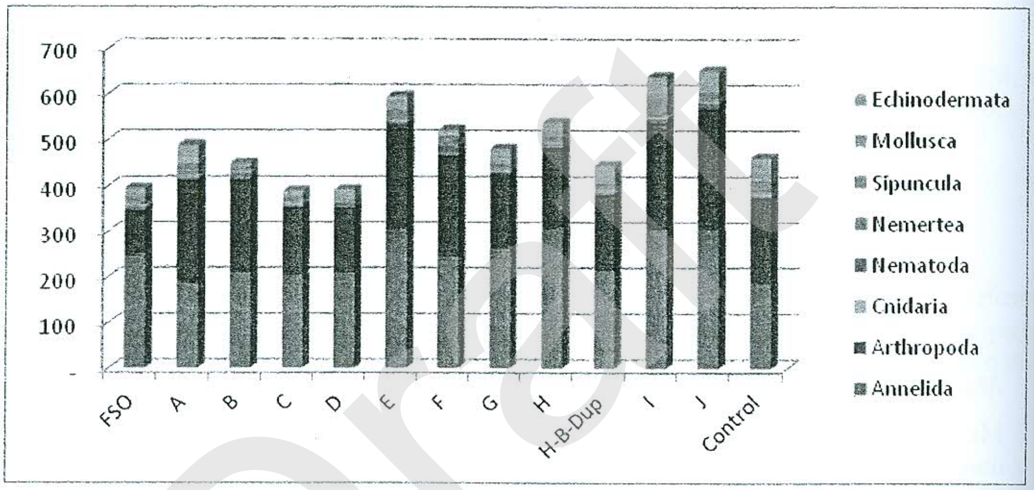
Source: 2010 EBS

Density

During the 2010, survey, the macrobenthic density of all survey sites varied from 387 – 650 individuals/m^2 with a mean of 494 ± 89 individuals/m^2. The lowest density of benthos was found in the station C, 387 individuals/m^2. The highest density was found at station J, 650 individuals/m^2.

In general, density of benthos from all stations was quite high compared to other studies in the Gulf of Thailand in 2009 (Plathong, 2010). In 2009, density of benthos in the western coast of the Gulf of Thailand varied from 230 – 490 individuals/m^2 (380 ±135 individuals/m^2). **Figure 3-19** shows the benthic composition and density for each station.

Figure 3-19: Benthos Composition and Density in the Project Area (individuals / m^2)

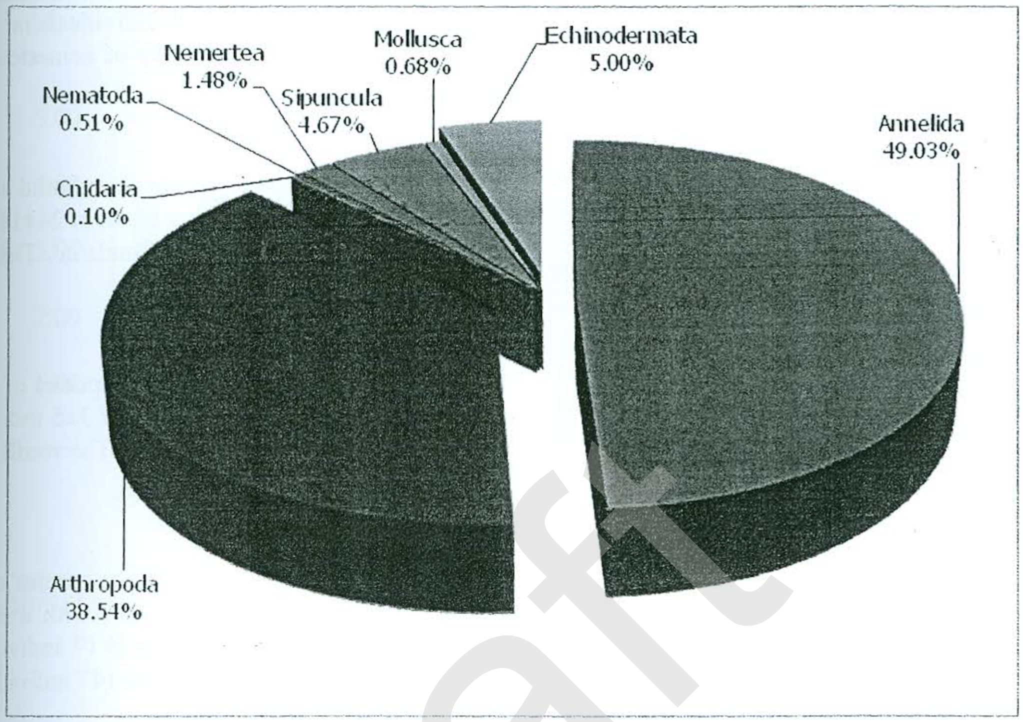


Source: 2010 EBS

Benthos Composition

Polychaetes (annelids) and crustaceans (anthopods) were the dominant phylum in benthic communities at all sites, accounting for 81.16 – 92.54%, average 87.57 ± 3.09% of organisms (**Figure 3-20**).

Figure 3-20: Composition of Benthos Community in the Project Area



Source: 2010 EBS

A description of the different benthic phyla present in the project area is provided below.

Phylum Annelida

Annelids were found at all 12 sites. They are the second most dominant group of benthos with 74 species of polychaetes found in the project area. The density varied from 183 – 303 individuals/m^2 with an average of 241 ± 48 individuals/m^2. The lowest density of polychaetes were found at the control site with 183 individuals/m^2. The highest density of benthos were found at station J, where there were 303 individuals/m^2. In general, the diversity and density of Polychaete in the project area is high.

Phylum Arthropoda

Arthropods were found at all 12 sites. They were the most dominant group of benthos with 85 species of arthropods, mainly crustaceans, in the project area. The density varied from 100 – 263 individuals/m^2, with an average of 191 ± 45 individuals/m^2. The lowest density of crustacean was found at station FSO (100 individuals/m^2). The highest density of crustacean was found at station J (263 individuals/m^2).

Phylum Cnidaria

One species of anemone was found at 2 of 12 stations, station H and the control station.The density varied from 0 – 3 individuals/m^2.

Phylum Nemertea

Nemerteans were found at 10 of the 12 stations. Five species of nemerteans were found in this study. The density varied from 0 – 20 individuals/m^2, with a mean of 7±6 individuals/m^2. No nemerteans were found in the samples from Stations G and H. The highest density of nemerteans was found at station F.

Phylum Sipuncula

Peanut worms were found at all stations. Eight species of peanut worms were found at the study sites. The density of peanut worms varied from 7 – 53 individuals/m^2, with a mean of 24±11 individuals/m^2. The lowest density of peanut worms was found at station D with 7 individuals/m^2. The highest density of peanut worms was found at station I with 53 individuals/m^2.

Phylum Mollusca

Mollusks are marine snails and clams. They were found at 7 stations. Three species of mollusks found in this study. The densities range from 0 – 17 individuals/m^2, with a mean of 3±5 individuals/m^2. The highest density of mollusks was found at station H with 17 individuals/m^2. The result indicate a high variability of mollusk density.

Phylum Echinodermata

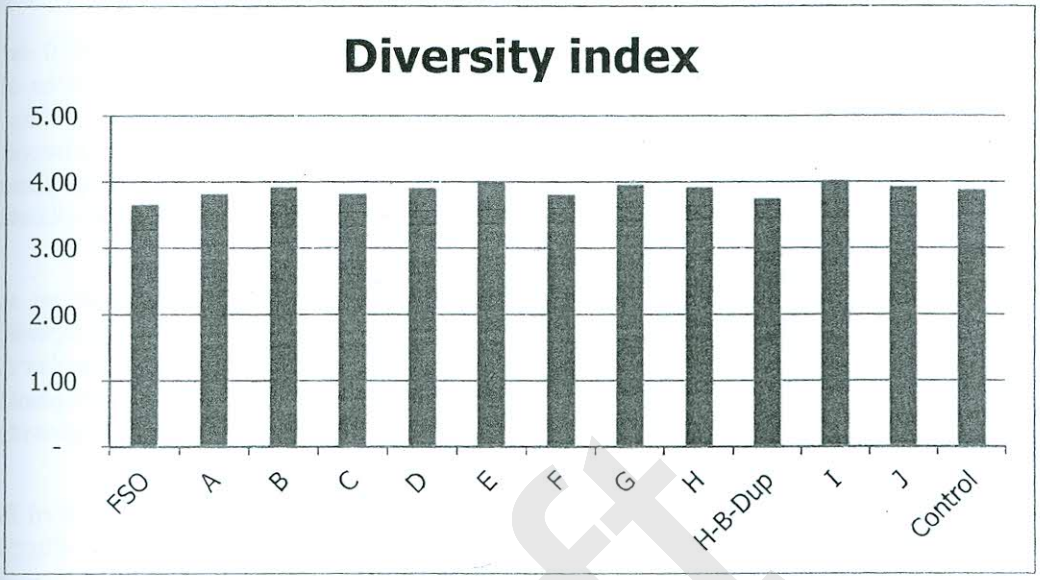
Echinoderms are including bristle star, sea urchin and sea cucumber. Eight species of echinoderms were found in this study. The densities range from 7 – 47 individuals/m^2, with a mean of 25±12 individuals/m^2. The lowest density of echinoderms was found at station B (7 individuals/m^2). The highest density of echinoderms was found at station J and the control station (47 individuals/m^2).

Diversity Index

The diversity index of benthos in the project area was 3.65 – 4.00, with a mean of 3.86±0.10.

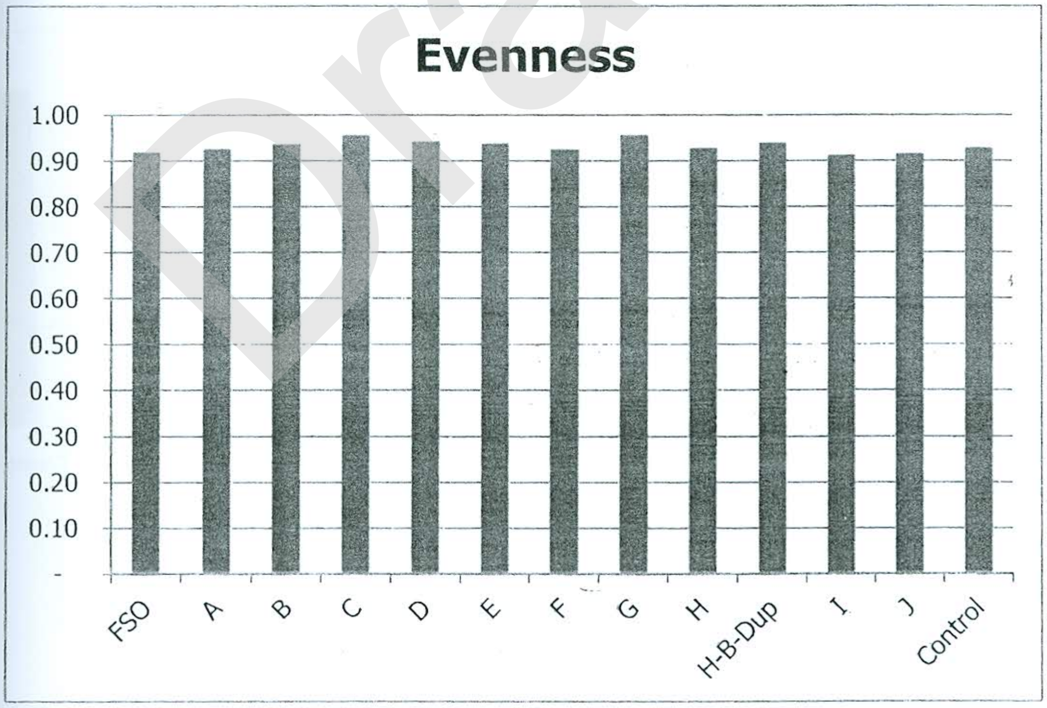
The highest value of diversity index at the station level (combined triplicated grabs) was found at station I (4.00). Overall, there was no difference in diversity index between stations (**Figure 3-21**). In general, the diversity index of benthos in the project area was quite high at all stations. The Evenness index at all stations was also high (>0.9). There was no difference between stations (**Figure 3-22**). The variability in benthic diversity index and evenness index over the entire project area is only slightly greater than at Station H. The result indicates a good distribution of each species composition.

Figure 3-21: Diversity Index of Benthos in the Project Area



Source: 2010 EBS

Figure 3-22: Evenness Index of Benthos in the Project Area



Source: 2010 EBS

3.4.1.3 Phytoplankton

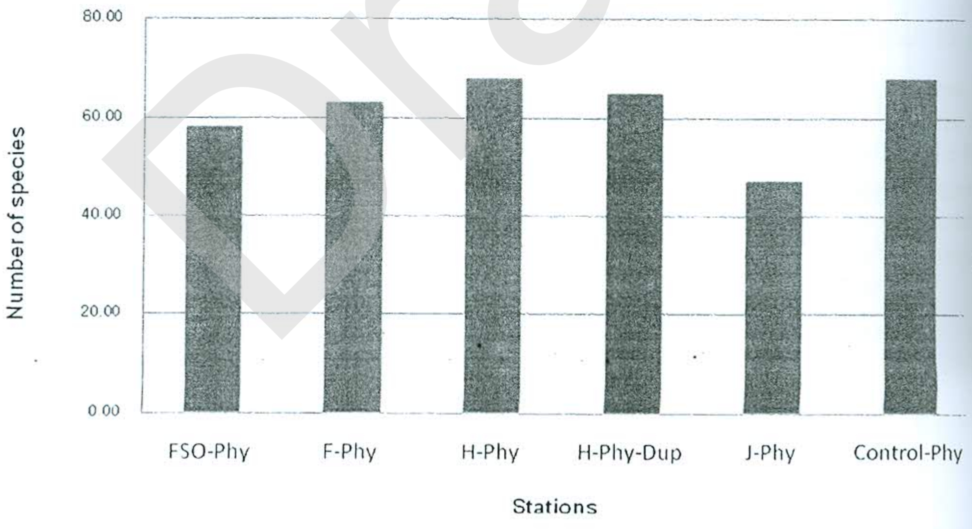
Species Richness

The phytoplankton collected at six stations in the project area during the 2010 survey included 28 families, 37 genera and 89 species of phytoplankton. There are three divisions of phytoplankton: Division Cyanophyta composed of 2 genera/ 4 species of blue green algae (Class Cyanophyceae); Division Chlorophyta composed of 1 genus, 1 species of green algae)(Class Chlorophyceae); Division Chromophyta composed of 20 genera/ 48 species of diatoms (Class Bacillariophyceae), 13 genera/34 species of dinoflagellates (Class Dinophyceae) and 1 genus/2 species of silicoflagellates (Class Dictyochophyceae).

The number of phytoplankton species varied from 47 – 68 species with an average of 62±8 species/station (**Figure 3-23**). The station with the maximum number of phytoplankton species was the control station (Control-Phy) with 68 species. The station with the least number of phytoplankton species was station J (J-Phy) with 47 species. The variability in number of phytoplankton species over the entire project area is slightly greater than at Station H. **Table 3-9** provides a list of all phytoplankton species collected at the project area.

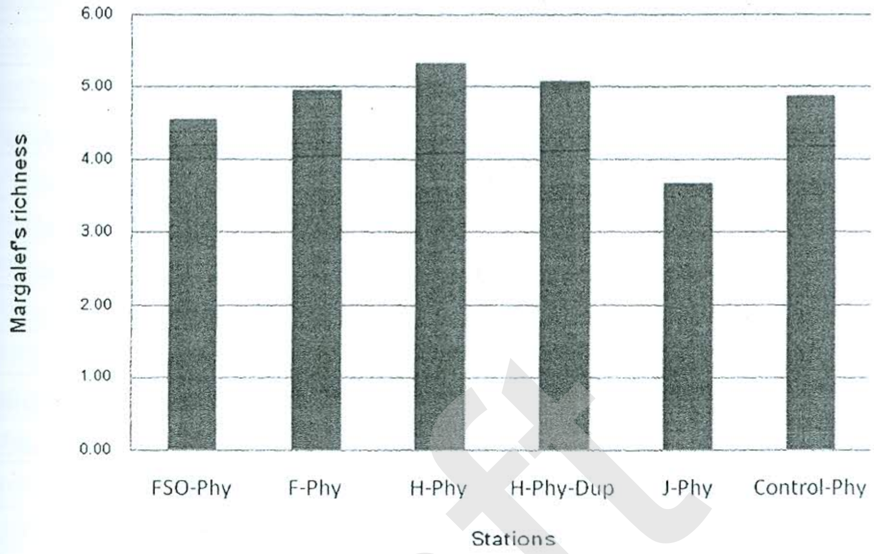
The Margalef's richness index was calculated for all stations. The richness ranked from 3.67 – 5.33 with an average of 4.74±0.59. The highest richness was found at station H (H-Phy:5.33).The lowest richness was found at the station J (J-Phy: 3.67) (**Figure 3-24**).

Figure 3-23: Number of Phytoplankton Species in the Project Area



Source: 2010 EBS

Figure 3-24: Richness Index of Phytoplankton in the Project Area



Source: 2010 EBS

Table 3-9: Phytoplankton Species Present in the Project Area

No.	Species of phytoplankton	No.	Species of phytoplankton
	Taxa		**Suborder Rhizosoleniineae**
	Division Cyanophyta		**Family Rhizosoleniaceae**
	Class Cyanophyceae	13	*Guinardia cylindrus*
	Order Nostocales	14	*Guinardia striata*
	Family Oscillatoriaceae	15	*Rhizosolenia styliformis*
1	*Oscillatoria erythraea*	16	*Rhizosolenia pungens*
2	*Oscillatoria* sp.1	17	*Rhizosolenia bergonii*
3	*Oscillatoria* sp.2	18	*Rhizosolenia formosa*
	Family Nostocaceae	19	*Rhizosolenia imbricata*
4	*Richelia intracellularis*	20	*Rhizosolenia* sp.4
	Division Chlorophyta		**Suborder Biddulphiineae**
	Class Chlorophyceae		**Family Hemiaulaceae**
	Order Chlorococcales	21	*Eucampia zodiacus*
	Family Chlorococcaceae	22	*Eucampia cornuta*
5	*Golenkinia radiate*	23	*Hemiaulus indicus*
	Division Chromophyta	24	*Hemiaulus sinesis*
	Class Bacillariophyceae	25	*Hemiaulus hauckii*
	Order Biddulphiales	26	*Hemiaulus* sp.2
	Suborder Coscinodiscineae		**Family Chaetoceraceae**
	Family Melosiraceae	27	*Bacteriastrum comosum*
6	*Paralia sulcata*	28	*Bacteriastrum hyalinum*
	Family Coscinodiscaceae	29	*Bacteriastrum furcatum*
7	*Coscinodiscus* sp.2	30	*Chaetoceros diversus*
8	*Palmeria hardmaniana*	31	*Chaetoceros lorenzianus*
	Family Asterolampraceae	32	*Chaetoceros affinis*
9	*Asterolampra* sp.	33	*Chaetoceros peruvianus*
10	*Asteromphalus* sp.1	34	*Chaetoceros coarctatus*
	Family Hemidiscaceae	35	*Chaetoceros messanensis*
11	*Hemidiscus* sp.	36	*Chaetoceros pseudocuvisetus*
	Family Thalassiosiraceae	37	*Chaetoceros tortissimus*
12	*Lauderia annulata*	38	*Chaetoceros compressus*

No.	Species of phytoplankton	No.	Species of phytoplankton
39	*Chaetoceros didymus*		**Family Amphisoleniaceae**
40	*Chaetoceros denticulatus*	57	*Amphisolenia bidentata*
41	*Chaetoceros* sp.2		**Order Gonyaulacales**
42	*Chaetoceros* sp.3		**Family Ceratiaceae**
43	*Chaetoceros* sp,6	58	*Ceratium furca*
	Family Eupodiscaceae	59	*Ceratium fusus*
44	*Odontella sinensis*	60	*Ceratium extensum*
45	*Odontella mobiliensis*	61	*Ceratium tripos*
	Family Lithodesmaceae	62	*Ceratium tricoceros*
46	*Ditylum sol*	63	*Ceratium massiliense*
	Order Bacillariales	64	*Ceratium deflexum*
	Suborder Fragilariaceae	65	*Ceratium inflacum*
	Family Thalassionemataceae	66	*Ceratium schmidtii*
47	*Thalassionema nitzschioides*	67	*Ceratium cortortum*
48	*Thalassiothrix* sp.1	68	*Ceratium breve*
49	*Thalassiothrix* sp.2	69	*Ceratium kofoidii*
	Family Fragilariaceae	70	*Ceratium candelabrum*
50	*Fragilaria* sp.1	71	*Ceratium porrectum*
	Suborder Bacillariineae	72	*Ceratium horridum*
	Family Bacillariaceae		**Family Gonyaulacaceae**
51	*Pseudo-nitzschia* sp.	73	*Lingulodinium* sp.
	Family Naviculaceae		**FanilyPyrocystaceae**
52	*Navicula* sp.2	74	*Pyrocystis lunula*
53	*Navicula* sp.3		**Family Ceratocoryaceae**
	Class Dinophyceae	75	*Ceratocorys horrida*
	Order Dinophysiales	76	*Ceratocorys* sp.2
	Family Dinophysiaceae		**Family Pyrophacaceae**
54	*Dinophysis hastata*	77	*Pyrophacus horologium*
55	*Ornithocercus* sp.		**Family Cladopyxidaceae**
56	*Phalacroma doryphorum*	78	*Cladophyxis* sp.

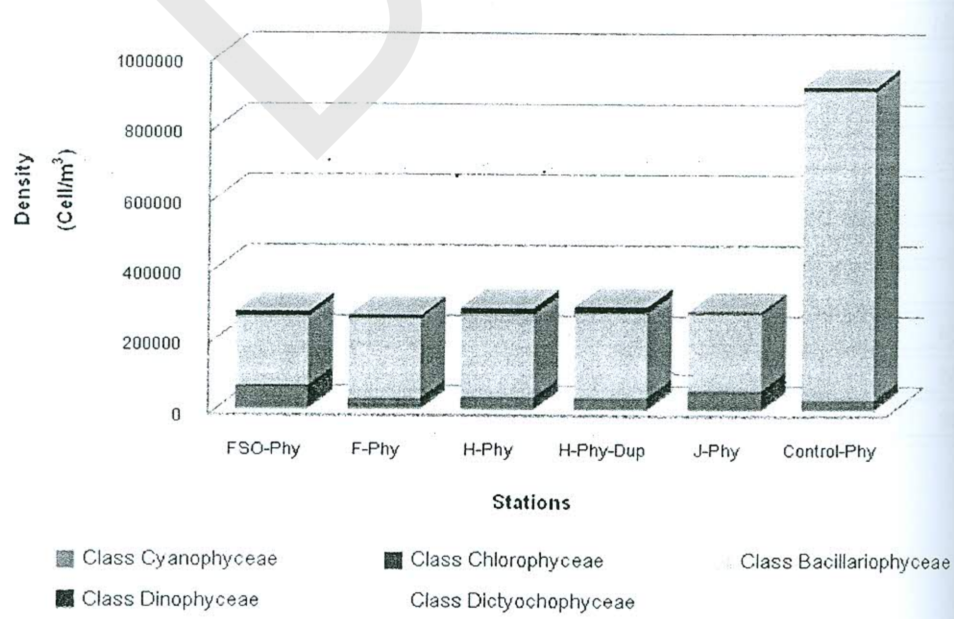
No.	Species of phytoplankton	No.	Species of phytoplankton
	Order Peridiniales		**Family Oxytoxaceae**
	Family Podolampadaceae	86	*Oxytoxum* sp.1
79	*Podolampas bipes*	87	*Oxytoxum* sp.3
80	*Podolampas elegans*		**Class Dictyochophyceae**
	Family Protoperidiniaceae		**Order Dictyochales**
81	*Protoperidinium conicum*		**Family Dictyochophyceae**
82	*Protoperidinium depressum*	88	*Dictyocha fibula*
83	*Protoperidinium divergent*	89	*Dityocha* sp.
84	*Protoperidinium* sp.2		
85	*Protoperidinium* sp.7		

Source: 2010 EBS

Density of Phytoplankton

The density of phytoplankton at the six stations in the project area during the 2010 survey varied between $2.68x10^5$ – $9.18x10^5$ cell/m^3, with an average of $3.89x10^5 \pm 2.60x10^5$ cell/m^3 (**Figure 3-25**). The highest density of phytoplankton was found at the control station (Control-Phy with $9.18x10^5$ cell/m^3), followed by station H (H-Phy-Dup and H-Phy with $2.95x10^5$ and $2.91x10^5$ cell/m^3 respectively). The lowest density of phytoplankton was found at station F (F-Phy with $2.68x10^5$ cell/m^3). These results are comparable with the results of a survey done in Block 8-38 in the Gulf of Thailand in 2010, where densities of phytoplankton in the project area were between $4.36x10^4$ – $1.04x10^5$ cell/m^3, with an average of $7.13x10^4 \pm 1.96x10^4$ cell/m^3 (IEM, 2010).

Figure 3-25: Phytoplankton Composition and Density in the Project Area



Source: 2010 EBS

Composition of Phytoplankton

During the 2010 survey, diatoms (Class Bacillariophyceae) were the most abundant group of phytoplankton and the main composition of phytoplankton at all stations. Their densities varied from $1.93x10^5$-8.73 $x10^5$cell/m^3, with an average of $3.29x10^5$±$2.67x10^5$ cell/m^3 (84.79% of the total number of phytoplankton). The diatoms were composed of 20 genera of 48 species.The most diverse diatom genus was *Chaetoceros* with 14 species, followed by *Rhizosolenia* with 6 species. The most abundant diatom group was *Thalassiothrix sp.1* (1.19 $x10^6$ ±$4.14x10^5$cell/m^3), followed by *Thalassiothrix sp.2* ($1.49x10^5$±$4.77x10^4$ cell/m^3). The lowest density of diatom were *Palmeria hardmandiniana* (100±48.80 cell/m^3) and *Odontella mobiliensis* (100±48.80 cell/m^3).

Blue green algae (Class Cyanophyceae) were the second most abundant phytoplankton group. Blue green density varied from $2.83x10^4$- $6.43x10^4$ cell/m^3, with an average of $4.08x10^4$±$1.48x10^4$cell/m^3()10.50% of the total number of phytoplankton). There were 2 genera of 4 species of blue green algae. The most diverse blue green algae were *Oscillatoria* spp. with 3 species.The blue green algal species with the highest density was *Oscillatoria* sp.1 (1.94 $x10^5$ ± 6.24 $x10^4$ cell/m^3), followed by *Richelia intracellularis* (3.76 $x10^4$±1.19 $x10^4$cell/m^3) and the lowest density was *Oscillatoria* sp.2 (5.2 $x10^4$ ±$1.67x10^3$cell/m^3).

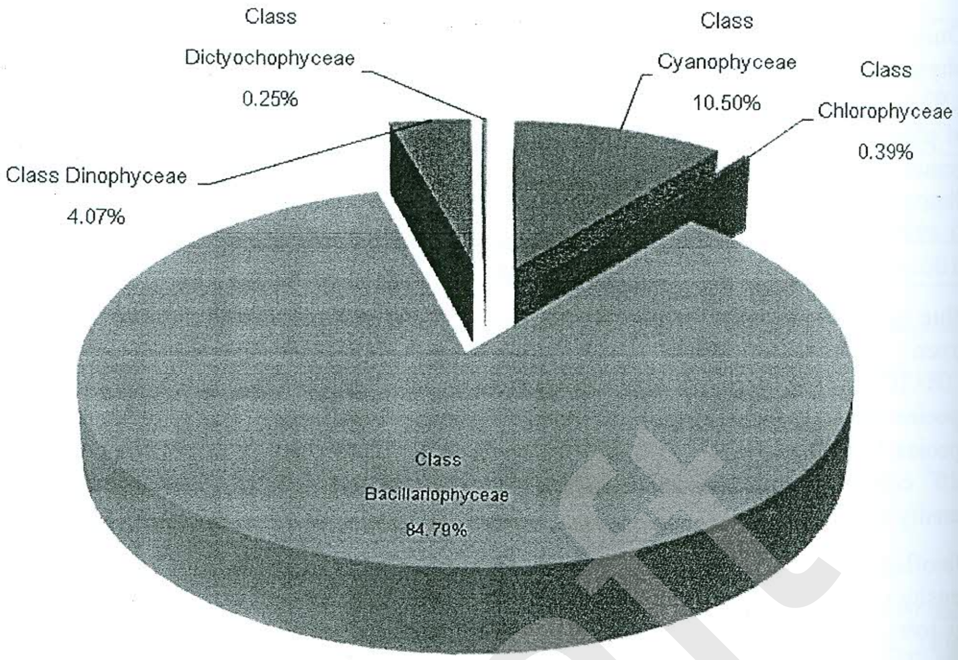
Dinoflagellates (Class Dinophyceae) were the third most abundant group of phytoplankton. The density varied from $7.2x10^3$- $22.5x10^3$ cell/m^3 with an average of $1.58x10^4$±$6.08x10^3$cell/m^3 (4.07% of the total number of phytoplankton). There were 13 genera, 34 species of dinoflagellates in the project area. The most diverse dinoflagellate genus in the project area was *Ceratium* (15 species), followed by *Protoperidinium* (5 species). The most abundant dinoflagellate was *Ceratium tricoceros* ($2.23x10^4$±$7.12x10^3$cell/m^3), followed by *Ceratium furca* ($1.33x10^4$±$4.29x10^3$ cell/m^3). The least abundant were *Ceratium deflexum, Ceratium kofoidii* and *Ceratocory s*sp.2 (each 100 cell/m^3).

Green algal (Class Chlorophyceae) density varied from $8x10^2$-25 $x10^2$ cell/m^3, averaging 1.52 $x10^3$±$6.70x10^2$cell/m^3. Only 1 species of Green algae was found: *Golenkinia radiata* with an average $9.10x10^3$±$2.93x10^3$ cell/m^3 (0.39% of the total number of phytoplankton).

Silicoflagellates (Class Divtyochophyceae) had the lowest density of phytoplankton during this survey. The densities varied from 7.00 $x10^2$ to $12.00x10^2$ cell/m^3, with an average of $5.67X10^2$±$2.25x10^2$ cell/m^3 (0.25% of the total number of phytoplankton). There was 1 genus with 2 species (*Dictyocha fibula* and *Dictyocha* sp.). The highest density was for *Dictyocha* sp. (4.5 $x10^2$±$1.43x10^2$ cell/m^3), the density for *Dictyocha fibula* was 1.3 $x10^2$ ±$4.42x10^2$ cell/m^3.

Figure 3-26 presents the detailed results from the 2010 survey. These results are comparable with those of a survey done in Block 8-38 in the Gulf of Thailand in 2010, where there were similarly five classes of phytoplankton: blue green algae (Class Cyanophyceae), green algae (Class Chlorophyceae), diatoms (Class Bacillariophyceae), dinoflagellates (Class Dinophyceae) and silicoflagellate (Class Dictyochophyceae) (IEM, 2010).

Figure 3-26: Composition of Phytoplankton in the Project Area

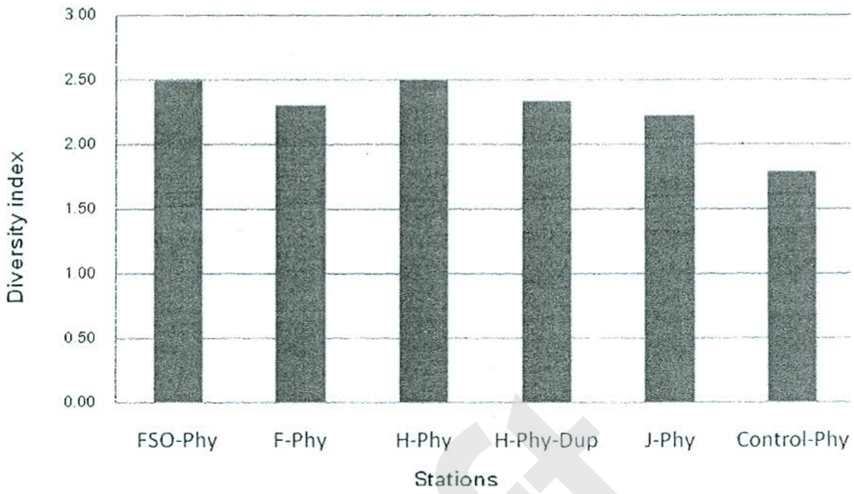


Source: 2010 EBS

Diversity Index

The diversity index at all six stations in the project area varied from 1.78 – 2.49, with an average of 2.27±0.26 (**Figure 3-27**). The highest diversity index was found at station H-Phy (2.49), followed by station FSO-Phy (2.48). The lowest diversity index was found at the control station (Control-Phy: 1.78). The variability in phytoplankton diversity index over the entire project area is slightly greater than at Station H. However, this is within the natural variability for marine biota. For example, a survey done in Block 8-38 in the Gulf of Thailand in 2010 showed that the diversity index varied from 2.92 - 3.40 between sampling stations (IEM, 2010).

Figure 3-27: Diversity Index of Phytoplankton in the Project Area

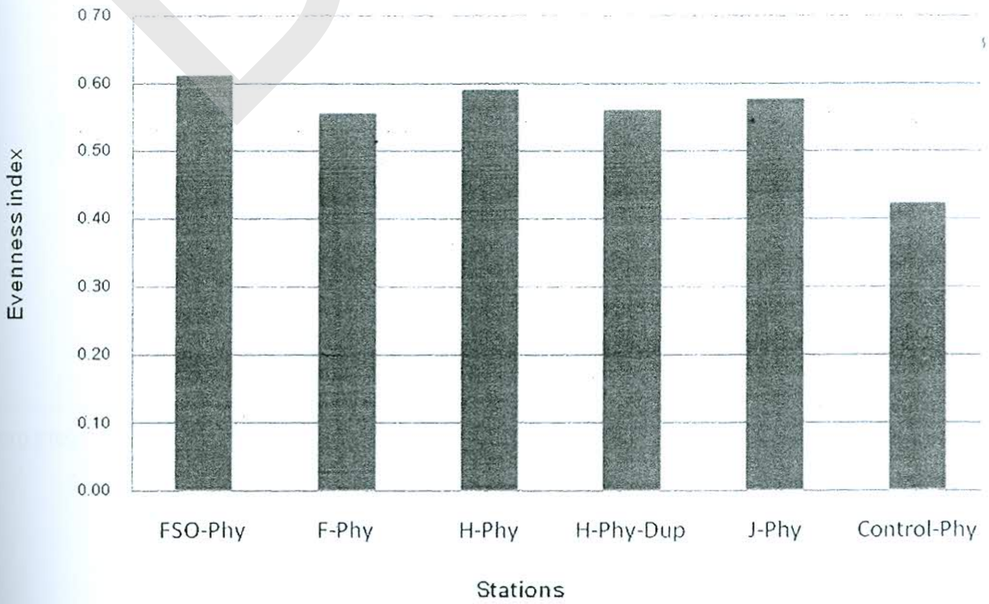


Source: 2010 EBS

Evenness Index

The evenness index of each station in the project area varied from 0.42-0.61 with an average of 0.55±0.067 cell/m^3. The highest evenness index of phytoplankton was found at the station FSO-Phy (0.61). The lowest evenness index was found at the station Control-Phy (0.42). **Figure 3-28** presents the evenness index found in the project area. The variability in phytoplankton evenness index over the entire project area is greater than at Station H.

Figure 3-28: Evenness Index of Phytoplankton in the Project Area



Source: 2010 EBS

3.4.1.4 Zooplankton and Larvae

Zooplankton (larger than 330 microns) found in the project area during the 2010 survey consisted of 50 taxa. The number of taxa per stations varied from 34 to 38. The zooplankton in the project area can be identified into nine phyla: Cnidaria, Ctenophora, Annelida, Arthropoda, Chaetognatha, Ectoprocta, Mollusk, Echinodermata and Chordata. The density of zooplankton in the project area varied from 2,092 – 6,279 individuals /100 m^3 with an average of 4,124±1,766 individuals /100 m^3. The highest density of zooplankton was found at station J (6,279 individuals /100 m^3). The lowest density of zooplankton was found at station H (2,095 individuals /100 m^3). In general, there was little difference between stations in the project area (**Table 3-10**, **Figure 3-29**).

Arthropoda: Crustacean

Zooplankton in the phylum Arthropoda, Class Crustacea, was the dominant group in all stations: 24.40 – 53.52 % (41.56±10.10 %) of zooplankton in the project area (**Figure 3-30**). The highest density of crustaceans was found at the Control station (2,912 individuals/100 m^3, **Table 3-10**). The lowest density of crustacean was found at station H (510 individuals /100 m^3). The common crustaceans found at all stations were Ostracod and Copepod, which contributed 15 – 48% (34.57±11.25 %) of the total zooplankton.

Larvae

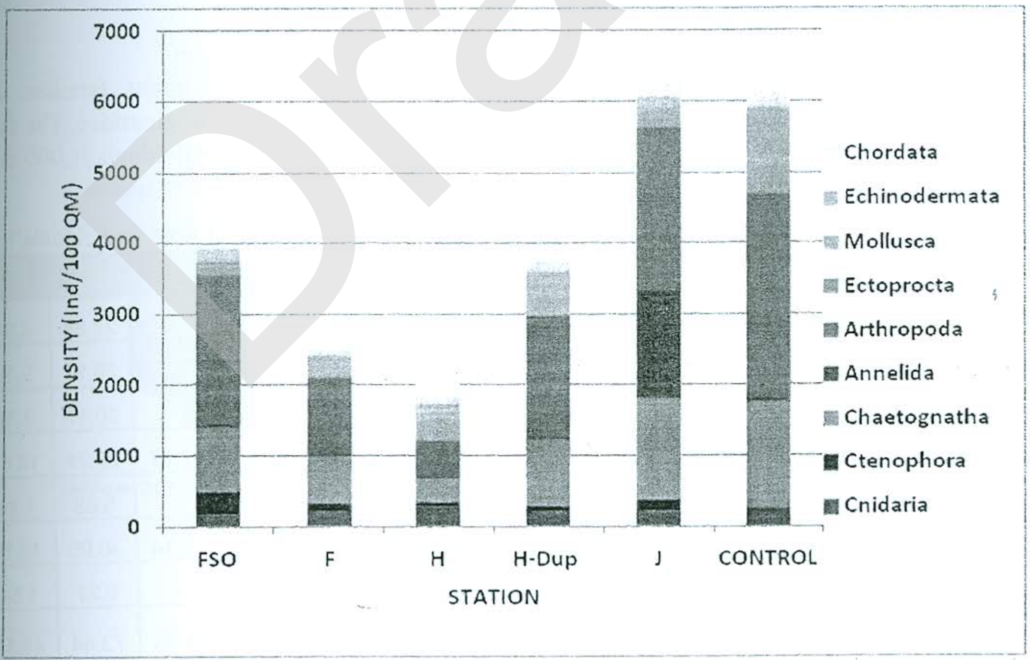
Meroplankton found in the project area consisted mainly of larvae of shrimp, stomatopod, crab, mollusk, polycheate, tanaid and echinoderms. There were important economic crustaceans including Acetes, Lucifer and Mysidin the project area. The densities of larva in the project area varied from 457 to 2,333 individuals /100 m^3 (average 1,083±741).

Table 3-10: Density of Zooplankton in the Project Area (individuals/100 m³)

Phylum	FSO	F	H	H-Dup	J	CONTROL
Cnidaria	141	197	245	187	191	216
Ctenophora	345	112	84	80	180	38
Chaetognatha	913	682	349	962	1439	1486
Annelida	34	36	17	40	1506	34
Arthropoda	2108	1063	510	1704	2305	2912
Ectoprocta	10	4	3	13	6	0
Mollusca	136	161	299	284	281	440
Echinodermata	58	144	215	307	141	758
Chordata	194	144	369	157	230	273
Total	**3939**	**2543**	**2092**	**3734**	**6279**	**6158**

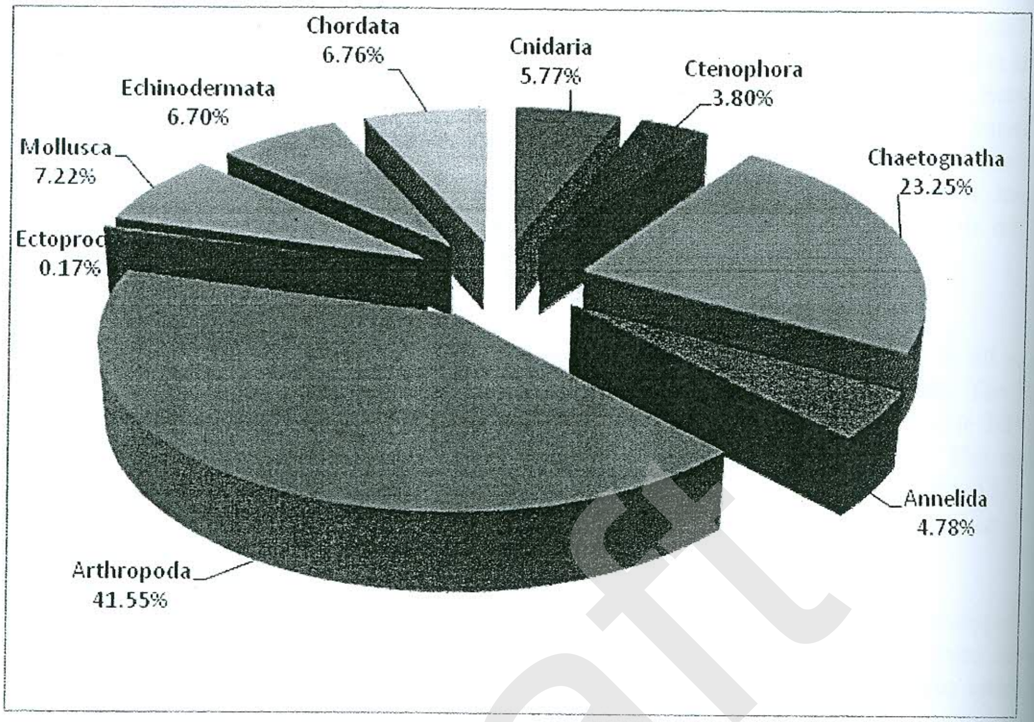
Source: 2010 EBS

Figure 3-29: Zooplankton Composition and Density in the the Project Area



Source: 2010 EBS

Figure 3-30: Composition of Zooplankton in the Project Area



Source: 2010 EBS

Fish Larvae

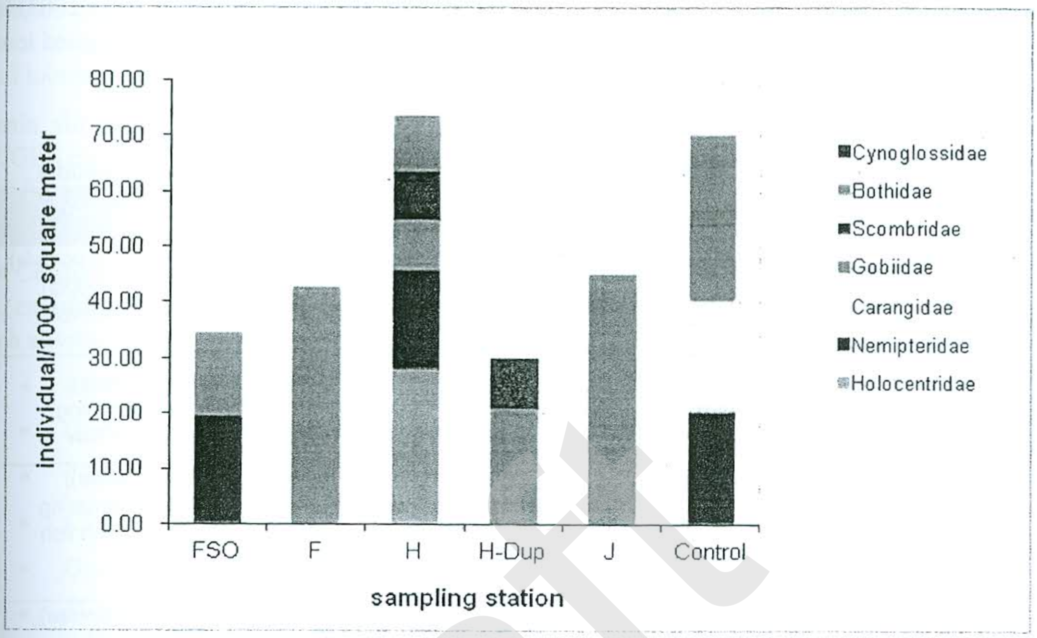
Fish larvae found in the project area belonged to seven different families: Holocentridae, Nemipteridae, Carangidae, Gobiidae, Scombridae, Bothidae, and Cynoglossidae. The densities at each station varied from 30 – 73 individuals /1,000 m^3 (average 49±18 individuals /1,000 m^3; **Table 3-11**, **Figure 3-31**, **Figure 3-32**).

Table 3-11: Density of Fish Larvae and Fish Eggs in the Project Area (individuals/1000 m^3)

Family	FSO	F	H	H-Dup	J	Control	min	max	mean	SD
Holocentridae	-	-	27.84	-	-	-	-	27.84	4.64	10.73
Nemipteridae	19.29	-	17.77	-	-	20.17	17.77	20.17	9.54	9.54
Carangidae	-	-	-	-	-	20.17	-	20.17	3.36	10.08
Gobiidae	15.09	12.30	8.88	-	14.81	29.71	17.77	29.71	13.47	9.38
Scombridae	-	-	8.88	-	-	-	-	8.88	1.48	12.01
Bothidae	-	30.05	10.07	20.74	30.03	-	20.14	30.05	15.15	12.01
Cynoglossidae	-	-	-	9.21	-	-	-	9.21	1.54	27.89
Total	34.38	42.35	73.44	29.95	44.84	70.05	29.95	73.44	49.17	18.32

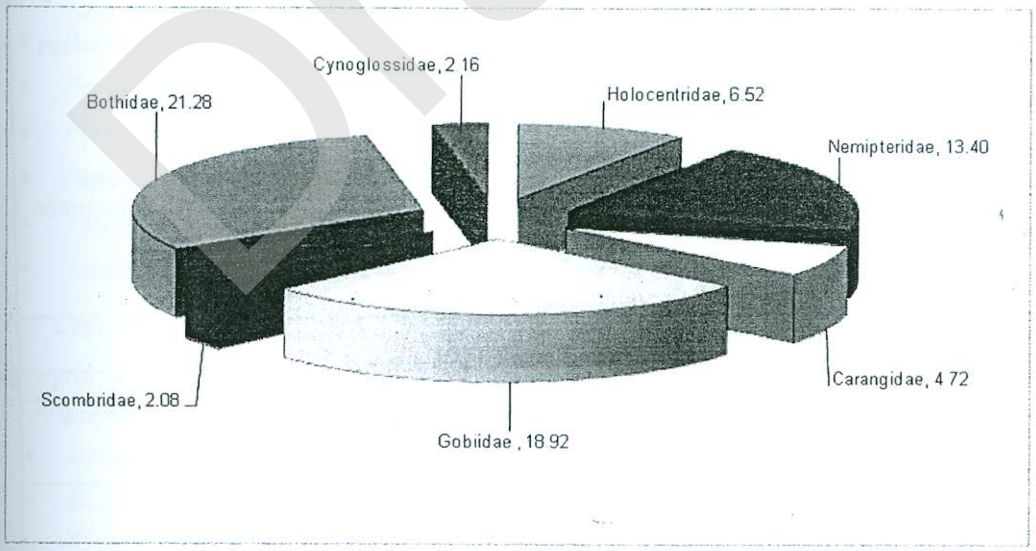
Source: 2010 EBS

Figure 3-31: Fish Larvae Composition and Density in the Project Area



Source: 2010 EBS

Figure 3-32: Composition of Fish Larvae in the Project Area



Source: 2010 EBS

3.4.1.5 *Fish*

The coastal waters of Cambodia support a large number of marine fish. Try (2003) lists 476 species of marine finfish. **Table 3-12** also shows species and by-catch observed as targeted in marine fisheries in Cambodia.

Table 3-12: Species Targeted in Marine Fisheries in Cambodia

Target species	Secondary 'by-catch'
Short mackerel (*Rastrelligerbrachysoma*), Indian mackerel (*R. kanagurt*), Indian Anchovy (*Stolephorus indicus*)	Torpedo scad (*Megalaspis cordyla*), Longtail tuna (*Thunnus tonggol*), other mackerels, tunas, bonitos (*Scombridae*)
Shrimp/Penaeidae sp.: *Penaeus semisulkatus, P. canaliculatus, P. latisulcatus, P. merguiensis*	Black tiger shrimp (*Penaeus monodon*), *P. silasi*, Swimming crabs (*Portunidae*), trash fish
Penaeus merguiensis, Mantis shrimp (*Squillidae*)	Trash fish, squid (*Loliginidae*), Scallops (*Pectinidae*), Swimming crabs (*Portunidae*), Scorpion fish (*Scorpaenidae*), Scallops (*Pectinidae*)
Swimming crabs (*Portunidae*), Mud crab/*Scylla serrata*	Sea bass & grouper (*Serranidae*), Scorpionfish (*Scorpaenides*), Mantis shrimp (*Squillidae*), Scallops (*Pectinidae*)
Indo-Pacific king mackerel (*S.guttatus*), Bluefin tuna (*T.thynnus*), Sharks, Seacatfish (*Ariidae*), Jacks (*Carangidae*), Mullet (*Liza argentea*), *Valamugil seheli*, Snapper (*Lutjanidae*), Short mackerel (*R. brachysoma*), Indian mackerel (*R. kanagurta*), Torpedo scad (*Megalaspiscordyla*), Silver pomfret (*Pampusargenteus*), Black Pomfret (*Formio niger*), Stingrays (*Dasyatidae*) Barramundi (*L. calcarifer*) Barracuda (*Sphyraenidae*), Terapons (*Terapontidae*)	Sea bass & grouper (*Serranidae*), Snappers (*Lutjanidae*), Breams (*Nemipteridae*), Drums & croakers (*Sciaenidae*), Sicklefish (*Drepaneidae*), Rabbitfish (*Siganidae*), Cutlassfish (*Trichiuridae*) Butterfish (*Stromateidae*), Wolf herring, (*Chirocentridae*), Lizardfish (*Synodontidae*).
Swimming crab (*Portunidae*), Mud crab (*Scylla serrata*), Squid (*Loliginidae*)	
Mixed species	
Nurse shark (*Orectolobidae*), Requiem shark (*Carcharhinidae*), Stingray (*Dasyatidae*), Seabass & grouper (*Serranidae*), Snapper (*Lutjanidae*)	
Mixed fish species Peregrine shrimp (*Metapenaeu*), Sepiolid squid (*Sepiolidae*), Octopus (*Octopus sp.*), Squid (*Loliginidae*), Very small shrimp (for shrimp paste)	Multi-species juvenile fish and shrimp
Grouper (*Serranidae*), Mixed coral reef fish	Giant clams (*Tridacnagigas*), Spidershell (*Lambis*)

Source: Touch & Todd, 2001

3.4.1.6 *Shrimp and Prawns*

Ten species were identified in the Gulf of Thailand: banana shrimp, jumbo tiger prawn, tiger prawn (*Penaeus monodon*), white shrimp (*Penaeus vannamei*), king prawn, school prawn, other shrimp, flathead lobster, mantis, and acetes (ECOST, 2007).

The main shrimp species in the Gulf of Thailand identified for the South China Sea Project (a UNEP/GEF project aimed at reversing environmental degradation trends in the South China Sea and Gulf of Thailand) are *Penaeus merguiensis* and *P. japonicas*.The spawning seasons for these two species are January to March and September to December (UNEP/GEF/SCS, 2006).

Marine Conservation Cambodia, an organization involved with protecting and conserving Cambodia's marine environment, has identified and photographically documented 16 different species through its research ativities. They are:

- *Anchisquilla fasciata*
- *Carinosquilla multicarinata*
- *Clorida decorate*
- *Cloridopsis scorpio*
- *Dasycaris zanzibarica*
- *Erugosquilla woodmasoni*
- *Miyakea nepa*
- *Penaeus latisulcatus*
- *Penaeus merguiensis*
- *Penaeus monodon*
- *Penaeus semisulcatus*
- *Periclemenes brevicarpalis*
- *Periclemenes tenuipes*
- *Phyllognathia certophthalmus*
- *Tozeuma armatum*
- *Tozeuma armatum* variation

3.4.1.7 *Cephalopods (cuttlefish, squid, octopus and chambered nautilus)*

The key squid and cuttlefish species in the Gulf of Thailand identified for the South China Sea Project's Regional Working Group on Fisheries (2002-2008) are:

- *Loligo duvaucel*
- *L. chinensi*
- *Sepia aculata*
- *S. recurvirostra*
- *S. pharaonis*

3.4.1.8 *Crabs*

Crabs can be found throughout the Gulf of Thailand. Crabbing takes place year-round (peak abundance in the central Gulf occurs during March-April), all along the Gulf coast.