Improved management approach to oil spill response of the gas-to-liquid project fuels

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DEDICATION

I dedicate this study first and foremost to Almighty God for preserving, providing and nourishing me during my training and study in South Africa under the auspices of Excravos Gas-To-Liquid (EGTL) Project.

♣

To my Parents (Anthony & Cecilia Chukwu): for their support, spiritual and temporal, I honour You! It would not have been possible without your blessings.

♣ ♣

I also dedicate this work to my brothers and siblings, who always believed in me.
Benjamin, Kingsley, Regina, Theresa, Pricilla, Georgina, & Agnes:
I salute you all!

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This dedication would not be complete without mention of my lovely wife, who sacrificed for my dreams. I honour you Chidinma Ogonna Chukwu (nee Okoroji) for standing by me.

♣ ♣ ♣ ♣

Finally, I re-dedicate this project work to the Glory of God, the Father whose faithfulness endures forever.

♣ ♣ ♣ ♣ ♣

Improved Management Approach to Oil Spill Response of the Gas-To-Liquid (GTL) Project Fuels

ABSTRACT

The demand for energy globally has remained unabated; technology and enterprise alignment is meeting this challenge. The current production of transport fuel is increasing with diesel fuel mostly in demand. This trend has continued to put more facilities on the world stage and is akin to inevitable spills in the outlook. The level of preparedness for such eventuality will make the difference in curbing emergencies in the future. The dwindling resources generated by 'Oil Spill Response enterprise' due to enhanced technology, reduction in large spill incidents, and neglect for small spills have continued to underscore their relevance in the industry. The demeanour would be to have a more positive nature to planning and prevention with greater ability to predict and effectively carry out response services when necessary. Getting to this height of adeptness would require a comprehensive risk and cost-benefit analysis of the scenarios.

The present body of knowledge for GTL diesel and related products is very vague on spill behaviour, control, and recovery in the tropics where commercial production of the product exist and so the emphasis in this dissertation is on actions that make a logical show given what is known. The 'Evaluation' through computer-based planning modelled (simulation) attempts and analytical modelling approach has shown "dispersion" as most influential weathering process for GTL-diesels and thus led to generation of 'GTL diesel loss rate' Chart for real time and forecast application. Furthermore, this analysis also helps corporate management and spill response contractors face the risks associated with spillage and reduce uncertainties by enhancing preventive measures via adoption of PERREP model. These innovative idea(s) are the best probable way out in spill response process with a proactive disposition that would allow adaptable techniques, materials and tools to be employed in local settings.

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LIST OF ACRONYMS

ADIOS – Automated Data Inquiry for Oil Spill

AGO – Automotive Gas Oil

ALARP – As Low As Reasonably Possible

BMP – Best Management Practice

BTEX – Benzene, Toluene, Ethylene, Xylene.

BTL – Biomass-To-Liquid

CTL – Coal-To-Liquid

DEQ - Department of Environmental Quality

DERV – Automotive diesel fuels

DoE – Department of Environment

DME – Dimethyl Ether

DRO – Diesel Range Organics

EGTL – Excravos Gas-To-Liquid

EIA – Environmental Impact Assessment

EPA – Environmental Protection Agency

ESI – Environmental Sensitivity Index map

FT – Fischer-Tropsch

GTL – Gas-To-Liquid

IR – Infra Red

ITOPF - International Tanker Owners Pollution Federation

ISB – In Situ Burning

ISCP – Integrated Spill Contingency Plan

LPG – Liquid Petroleum Gas

LSBF – Least Square Best Fit

NASA – National Aeronautics and Space Administration

NOAA—National Oceanic and Atmospheric Administration.

ODEQ – Oklahoma Department of Environmental Quality

OSCC – Oil Spill Coordinating Centre

OSRL – Oil Spill Response Limited

OVA – Organic Vapour Analysers

PAH – Polycyclic Aromatic Hydrocarbon

PM 10 – Particulates measuring less than 10 microns

PPM – Parts Per Million

PWU – Process Work-up Unit

SEIA – Socio – Economic Impact Assessment

SMDS – Shell Middle Distillate Synthesis

SPCC – Spill Prevention, Control and Counter-measures

TPH: Total Petroleum Hydrocarbon

US – United States

VHS – Video Home System

VOC – Volatile Organic Components

WCS – Worst-Case Scenario

1.0 CHAPTER ONE (INTRODUCTION)

1.1 DEFINITION OF OIL SPILLS AND SPILL CLASSIFICATIONS

Oil spill has been defined as an accidental release of oil into a body of water, as from a tanker, offshore drilling rig, or underwater pipeline, often presenting a hazard to marine life and the environment (Random House Unabridged Dictionary, 1997). In certain quarters it is defined as an accidental discharge of oil from pipeline or facilities (NISP Manual, 2002). The Wikipedia online encyclopedia defines an oil spill as the intentional or unintentional release of oil into the natural environment as a result of human activity (Wikipedia, 2006). It is 'unintentional' because it is unplanned for and as such requires prompt action to mitigate the potential effects to the environment. The 'release' is usually from process facilities, during transportation and when in use. The standard for oil spill definition may defer. It is at best defined in context as any discharge of oily substance, whether deliberate or accidental, that adversely or measurably alters the natural or cultural landscape (Sorrell, 2004)

A release event is described as a discharge of oil in harmful quantities that violate applicable water quality standards; which causes a film, sheen, or discoloration of the water surface; or cause sludge or emulsion deposit beneath the water surface. This spilt material includes oil of any kind and any form, such as petroleum and non-petroleum products (crude oil, refined petroleum products, gasoline, diesel, jet fuel, kerosene, edible and non-edible animal and vegetable oil, mineral oil, and other non-petroleum oils. For example oily refuse, oil mixed in waste or oily ballast and synthetic fuels). Oil is also released into the environment from natural geologic seeps on the seafloor, as along the California coastline (US-CFR: SPCC Rules and Regulations, 2002a).

Oil types are wide and varied, with crude oil been the biggest culprit in spill incidents of the past. The compositional data on crude oils have been used to characterise oil types as to the amounts of each group present in the oil, and thus predict the behaviour of the oil and the risk that oil poses to natural resources of concern. Based on this, we have three categories:

Light-weight components are characterised by:

• Hydrocarbon compounds containing up to ten carbon atoms

• A boiling range up to 150 degrees Centigrade
• Rapid and complete evaporation, usually within a day
• High water solubility; usually contributes >95% of water-soluble fraction
• High acute toxicity because they contain the monoaromatic hydrocarbons (benzene, toluene, xylene).which are soluble and toxic
• No potential for bioaccumulation (they evaporate instead)
• Mostly composed of alkanes and cycloalkanes which have relatively low solubility (and thus low acute toxicity potential)

These light ends evaporate so quickly that they do not persist in the environment.
Even though individual aromatic compounds have solubility of over 1,000 mg/L, they are rapidly removed from solution by evaporation. One important exception to this general rule is when the dissolved fraction is rapidly mixed into the water column under cold conditions.

Medium-weight components are characterised by:
• Hydrocarbon compounds containing between 10 and 22 carbon atoms
• A boiling range from about 150 to 400 degrees C
• Evaporation rates of up to several days, although there will be some residue which does not evaporate at ambient temperatures
• Low water-soluble fraction (at most a few mg/L)
• Moderate acute toxicity because they contain diaromatic hydrocarbons (naphthalenes) which are toxic in spite of their low solubilities
• Moderate potential for bioaccumulation and chronic toxicities associated with the diaromatic hydrocarbons
• Mostly Alkanes (aliphatic hydrocarbons) which are readily bio-degraded under the right conditions.

These medium-weight components pose the greatest environmental risks to organisms because the compounds are more persistent, they are biologically available, and the PAHs have high toxicities.

Heavy-weight components are characterised by:
• Hydrocarbon compounds containing more than 20 carbon atoms

• Almost no loss by evaporation
• Almost no water-soluble fraction
• Potential for bioaccumulation, via sorption onto sediments, otherwise not highly bio-available
• Potential for chronic toxicity, because they contain polynuclear aromatic hydrocarbons (phenanthrene, anthracene, etc.)
• Most of the components are waxes, asphaltenes, and polar compounds which do not have any significant bio-availabilities or toxicities
• Long-term persistence in sediments, as tar balls, or asphalt pavements

These heavier components pose little acute toxicity risks, except those due to smothering, because of the very low solubility of the individual compounds.
Animals have to be exposed via a sediment pathway or through the food chain.
More so, these are the most persistent components of oil and degradation rates are usually very slow.

Oil have generally been classified based on its properties, four types of oil in spill response categorisation are well known and accepted (NOAA, 1992) for which a general assessment of the behaviour and fate can be made. Breuel A, (1981a) groups them in classes and detailed their physical attribute. The harmonised classifications are shown below.

Class A: Type 1—Very Light Oils (Jet Fuels, Gasoline)
• Highly volatile (should all evaporate within 1-2 days). Highly flammable when fresh.
• High concentrations of toxic (soluble) compounds.
• Result: Localised, severe impacts to water column and intertidal resources.
• Duration of impact is a function of the resource recovery rate.
• No dispersion necessary. High fluidity, clarity, rapid spreading rate, strong odour
• No clean-up necessary. Poor adhesion to materials, flushing most effective in clean-up,
• Tendency for substrate penetration is higher, and generally form unstable emulsions.

Class B: Type 2—Light Oils (Diesel, No. 2 Fuel Oil, Light Crude)
• Moderately volatile; will leave residue (up to one-third of spill amount) after a few days.
• Medium to heavy Paraffin based oils, it has waxy and non sticky feel.

• Moderate concentrations of toxic (soluble) compounds, especially distilled products.
• Will "oil" intertidal resources with long-term contamination potential.
• Has potential for subtidal impacts (dissolution, mixing, sorption onto suspended sediments).
• It appears as fluid and emulsified easily on water. No dispersion necessary.
• Clean-up can be very effective. They are moderately removed by flushing.

Class C: Type 3—Medium Oils (Most Crude Oils)

• About one-third will evaporate within 24 hours. They are residual fuel oils, heavier asphaltic and mixed base crude oils in fluid state. Viscous, sticky or tarry, brown or black in colour.
• Maximum water-soluble fraction of 10-100 ppm.
• Oil contamination of intertidal areas can be severe and long-term. Smothering effect is visible. Substrate penetration is low, likely to sink in water.
• Oil impacts to waterfowl and fur-bearing mammals can be severe.
• Chemical dispersion is an option within 1-2 days. Forms stable emulsions.
• Clean-up most effective if conducted quickly.

Class D: Type 4—Heavy Oils (Heavy Crude Oils, No. 6 Fuel Oil, Bunker C)

• Heavy oils with little or no evaporation or dissolution. Non-fluid oils
• Water-soluble fraction is less than 10 ppm. Some high paraffin crude oils, residual oils.
• Heavy contamination of intertidal areas likely.
• Severe impacts to waterfowl and fur-bearing mammals (coating and ingestion).
• Long-term contamination of sediments possible.
• Weathers very slowly. Essentially non toxic in solid form, melts on heating
• Chemical dispersion seldom effective.
• Shoreline clean-up difficult under all conditions.

Oil spills are usually classified based on amount spilt and environment of incidence from a 'litre' to 'tonnes' of measure. It has also become very important to categorise spills in order to effectively determine the scale of clean-up operation required, as such deploy appropriate resources. Most classification, groups' oil spills into minor, medium and major spills.

The International Tanker Owners Pollution Federation Limited (ITOPF) classification is simply for historical vessel spill events and relates to spill size (<7 tonnes, 7-700 tonnes and >700 tonnes), although the actual amount spilt is also recorded (Historical Data: statistics, http://www.itopf.com/stats.html). This categorisation is either Small, Medium or Large spills and disregards location of spills:

Type of Spill	Quantity Released
Small Spills	< 7 tonnes
Medium Spills	7 – 700 tonnes
Large Spills	> 700 tonnes

Table 1.1: International Tanker Owners Pollution Federation Limited (ITOPF) classification.

The United Kingdom government groups' oil spill as seen below based on area of impact and extent as seen in the Carmarthenshire website (Categorisation of Spill): http://www.carmarthenshire.gov.uk/agendas/eng/COUN20020226/REP06_3.htm.

These classifications are:

Category A Spill: Minor spill of oil with coastal pollution likely or has occurred. In this situation, the extent of the pollution is so minor that the Local facility would be able to deal with it using its own resources without major disruption to normal work.

Category B Spill: Moderate spill of oil with coastal pollution likely, or has occurred. This situation would have a greater impact on the Local Authority, which might require the initiation of mutual aid and assistance to respond to the incident though still within the response capability of the Local facility.

Category C Spill: Large spill, or potentially large spill, of oil of major significance with coastal pollution possible, likely or has occurred. In this situation an Oil Spill Co-ordinating Centre (OSCC) would be set up to make an assessment of the extent and effects of the spill on the coastline. This response would involve wider participation.

The US Coast Guard utilises classification of Oil Spills based on the amount of oil discharged into the environment. They are three broad categories (minor, medium and major) see table below (http://www.uscg.mil/d14/units/msohono/hacp/9400.htm).

Type of Spill	Coastal Zone(offshore)	Inland Zone(onshore)
Major discharge	>100,000 gallons	>10,000 gallons
Medium discharge	>10,000 – 100,000 gallons	> 1,000 - <10,000 gallons
Minor discharge	<10,000 gallons	< 1,000 gallons

Table 1.2: US Coast Guard Classification of Oil Spills.

A major discharge (Worst-case discharge) is defined as a spill greater-than 100,000 gallons of oil in the coastal zone or, a spill greater-than 10,000 gallons in the inland zone.

A medium discharge (Maximum Most Probable Discharges) is defined as a spill greater than 10,000 but less than 100,000 gallons of oil in the coastal zone or, a spill greater than 1,000 but less than 10,000 gallons in the inland zone.

A minor discharge (Average Most Probable Discharges) is defined as a spill less than 10,000 gallons of oil in the coastal zone or, a spill less than 1,000 gallons in the inland zone.

In the event of an actual or potential medium or major oil spill, the US Coast Guard has adopted the format below in order to delegate the response outfit and strategy applicable during notification. This classification considers oil spills as either potential or actual and within the medium to major spill ranges (US Coast Guard http://www.uscg.mil/d5/msafety/rrt/rcp/Admin/CALLUPindex.html).

Type of Spill	Location	Quantity Released
Potential	Inland	over 10,000 gallons
Actual	Inland	over 1,000 gallons
Potential	Coastal	over 100,000 gallons
Actual	Coastal	over 10,000 gallons

Table1.3: US Coast Guard Potential Vs Actual Classification of Oil Spills.

Another scheme of Oil spill incidents are categorised into 'Tiers' as to the severity and resource requirements as elaborated by Oil Spill Response Limited (OSRL) (http://www.oilspillresponse.com/emergency/index.html) and adopted by The Malaysian Oil Spill Response System (http://www.american.edu/TED/malayoil.htm) and many other nations as shown below.

Tier 1 (Local/Industry): A minor incident that can be dealt with using the resources at a specific location or facility. It is site-specific and includes most shore-side industry with oil transfer sites, offshore installations and all vessels required to have a shipboard oil pollution emergency plan. It caters for small spill that may occur within port limits, oil terminals and depots as well as oil platforms.

Tier 2 (Area/Regional Councils): A larger incident that would require some mutual assistance of oil spill response resources within a region. These agencies are responsible for providing an operational response to oil spill incidents within their regions, and out to 12 nautical mile limit of the Territorial Sea and they will also respond to those spills for which no responsible party can be identified.

Tier 3 (DoE and National Action): A large or catastrophic spill that requires international assistance when a spill occurs within a region which is beyond the resources of the region. Spills which occur outside the Exclusive Economic Zone and over the National Continental Shelf are also the responsibility of the Department of Environments. It is activated also when the spill spreads into waters of neighbouring countries.

The obvious remains that there is no standardised method or parameter of classifying oil spills. It varies from system to system depending on what has been adopted. A close look will show that the terms are a bit different, but referring to similar circumstance.

1.2 OIL SPILLS AND THE WORLD PAST

Oil spill has been occurring ever since the creation of the world, though unconsciously to humanity. This may be as a result of unrecognisable impact to people's existence over the mediaeval times. In recent pasts since the advent of crude oil (petroleum), oil spill has become a crucial issue, a challenge that is affecting our lives, investments and environment. In the United States like so many other countries all over the world, Oil from natural seeps was in the water before the first spills from oil production. In the early 1500s, the Portuguese-born explorer Juan Cabrillo sailed into what is now Santa Barbara, California, and remarked on the oil he saw bubbling out from a natural seep (http://response.restoration.noaa.gov/topic subtopic entry.php?).

Oil spills happen all around the world. Analysts for the 'Oil Spill Intelligence Report', who track oil spills of at least 10,000 gallons (34 tons), reported that spills in that size range have occurred in the waters of 112 nations since 1960. But they also reported (Etkin 1997 in NOAA website) that oil spills happen more frequently in certain parts of the world. They identified the following "hot spots" for oil spills from vessels: the Gulf of Mexico (267 spills), the northeastern U.S. (140 spills), the Mediterranean Sea (127 spills), the Persian Gulf (108 spills), the North Sea (75 spills), Japan (60 spills), the Baltic Sea (52 spills), the United Kingdom and English Channel (49 spills), Malaysia and Singapore (39 spills), the west coast of France and north and west coasts of Spain (33 spills) and Korea (32 spills).

The biggest oil spill (9,000,000 barrels) ever recorded was the Arabian (Persian) Gulf spill in 1991 (http://www.oilspills.org/historic_oil_spills.html). The Exxon Valdez spills is one of the world most studied spills. It has been most popularised due to its extent and effects and ranks around the 35th largest spills of all time (http://www.itopf.com/stats.html). The World Glory Spill of 1968 in Durban and Castillo de bellver off Saldanha bay within off the coast of South Africa is also worthy of mention (http://www.oilspills.org/World Glory.htm). The Atlantic Empress spill and ABT Summer is ranked second and third largest spill respectively in the world as represented below.

POSITION	SPILL NAME	LOCATION	DATE	BARRELS
1	Arabian Gulf/Kuwait	Persian Gulf	1/19/1991	9,000,000
2	Atlantic Empress	Off Tobago, West Indies	1979	2,103,642 (287,000 tonnes)
3	ABT Summer	700 nautical miles off Angola	1991	1,905,739 (260,000 tonnes)
4	Nowruz Oil Field	Persian Gulf, Iran	2/4/1983	1,904,762
5	Castillo de Bellver	Off Saldanha Bay, South Africa	8/6/1983	1,847,101 (252,000 tonnes)
6	Amoco Cadiz	Brittany, France	3/16/1978	1,619,048
7	Haven	Genoa, Italy	1991	1,055,486 (144,000 tonnes)
	World Glory	Durban, South Africa	6/13/1968	334,043
37?	Exxon Valdez	Prince William Sound, AK	3/24/1989	240,500

Table 1.4: **Historical Compilation of Spill Incidents by Size and Location.**
(http://www.oilspills.org/historic_oil_spills.html, http://www.itopf.com/stats.html)

The incidence of large spills is relatively low and detailed statistical analysis is rarely possible. The number of large spills (>700 tonnes) has decreased significantly during the last thirty years (see ITOPF website on http://www.itopf.com/stats.html for further details). The vast majority of spills are small (i.e. less than 7 tonnes) and data on numbers and amounts is incomplete.

The United States National Academy of Sciences estimated that Earth's waters are polluted each year by about 2 billion litre of petroleum products (http://www.nrsm.uq.edu.au/iucn/pages/chap/12/main12.htm). This shows that the challenge of managing oil spills in the world today is increasing in complexity and magnitude. Oil spills threaten millions of miles of coastline, river systems, lakes, facilities and terrestrial habitat daily, particularly where there is extensive oil drilling, refining, and transportation. This may lead to serious and potentially permanent ecological damage due to chronic spills or Major spill occurrence.

1.3 CURRENT TRENDS

The increasing energy needs all over the world on annual basis has placed huge demand on production of refined crude oil. This need has greatly pushed the oil price at the pump level beyond the reach of the average citizenry of the world. This has also necessitated the drive for other sources and possibly better store of energy for people's use. Technological advancement in our world today is gradually cushioning the effect placed on crude oil by the production of synthetic fuels from synthetic gas.

The synthetic gas is usually gotten from oil shale, coal (CTL), biomass (BTL), or natural gas (GTL). These alternative sources of energy has been tested and proven adequate to complement crude oil. Recently GTL fuels have gained popularity in production due to its environmentally friendly nature at least at the consumer phase. This alternative source can be used to produce automotive diesel, jet fuels, lubricants, base chemicals, and Dimethl Ether (DME) which could in turn be used in diesel engines, gas turbines, power generating plants or as a substitute for Liquid Petroleum gas (LPG).

Statistics from Environmental Protection Agency (EPA) estimates that 24,000 oil spills occur each year in the USA, about 70 spills are recorded on the average each day, according to the Agency. Even though oil spills to the ocean are more public, fresh water spills are more frequent and often more destructive to the environment (http://www.ens-newswire.com/ens/jun2004/2004-06-10-09.asp. The same source claims also that "*...on average, one spill of greater than 100,000 gallons occurs every month from oil storage facilities and the entire transportation network.*" in the United States. In a similar light, figures from the Norwegian oil giant 'STATOIL shows that the number of unintentional oil spill incidents increased from 487m3 in 2004 to 534m3 in 2005 and spilt volume also increased from 186m3 in 2004 to 340m3 in 2005 due to increased operational activity (http://www.statoil.com/INF/SVG02304.nsf/0/44DEC5CB05F72FBAC1257111003E8C8F?Op...).

Moreover, dataset presented at the 'Fresh water Spills Symposium', in 2004 by John Temperelli of Garner Environmentals for the US coastal area shows that there are more spill incidence over time around the coast and less funding is put into "spill response" which may imply a low business ventures for the oil-spill response enterprise (see figure 1.1-1.3. curled from http://www.epa.gov/oilspill/pdfs/temperilli_04.pdf).

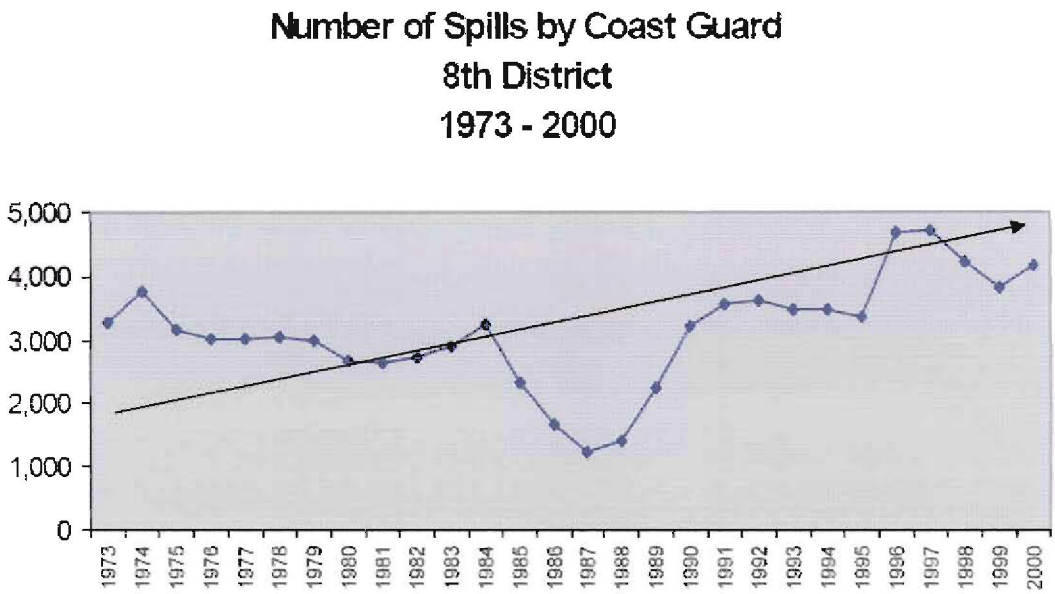


Figure 1.1 Number of Spill incidents (John Temperilli 2004.)

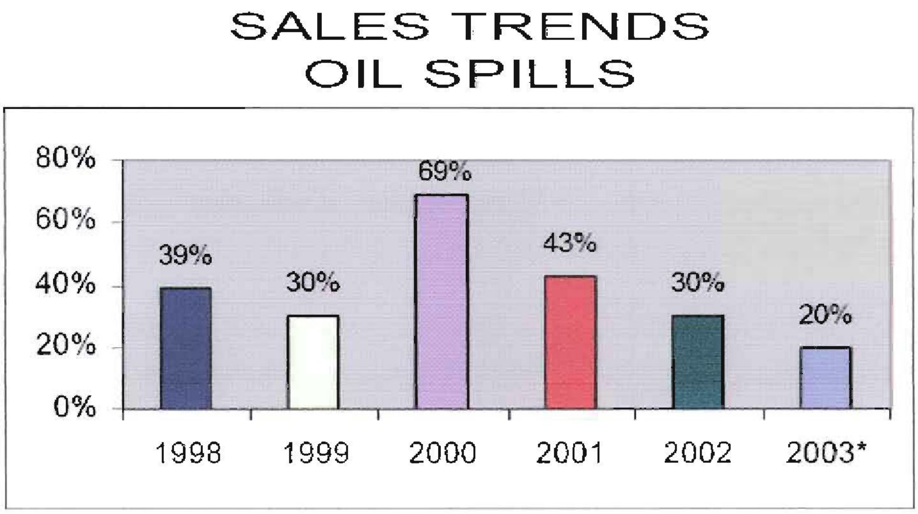


Figure 1.2 Sales Trend of oil Spill Enterprise (John Temperilli, 2004.)

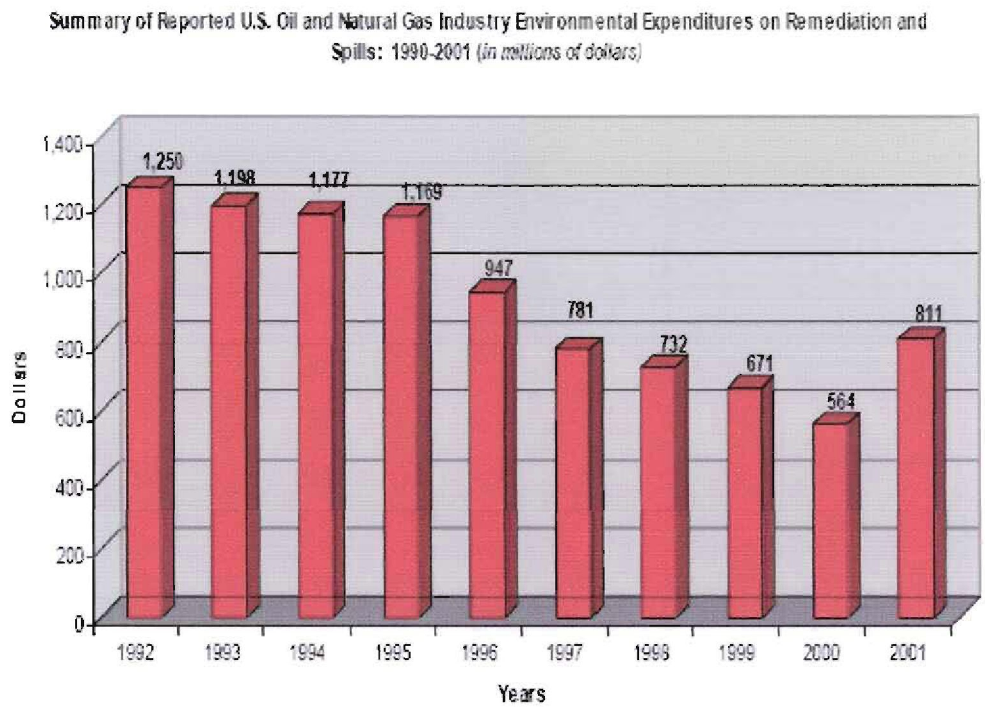


Figure 1.3 Expenditure Pattern for Oil Spill Remediation Activity

1.4 CHALLENGES AND NEEDS (PROBLEM STATEMENT)

The focus of this research is on synthetic diesel derived from natural gas (GTL). They are expected to play an increasingly important role in cushioning the global energy demand and as such are more likely to pose further threat to the incessant oil spillage ravaging the world today.

The present management of oil spill response is designed by policy and implementation in the oil and gas industry with focus on mitigating the environmental effect; eliminating threat to life; avoiding damage to assets, and preventing loss of crude oil and by product.

The greatest effects of spill have been on the environment (probably accounting for 90% or more of oil spill consequence) and threat to the way of life of people in affected areas over the years. It is worth noting that the increasing production of gas to liquid fuels all over the world is increasing and in no far future date may overtake the conventional source of energy which is known to be environmentally unfriendly and toxic. This trend seams to constitute life threatening position for the major score of oil spill response process actions as it is known today.

The threat emanates from the elimination of the environmental factor by 'spill response' actions as supposed by the oil spill incident of August 2001, in the pristine waters of Alaska. It cost the authorities over $3 million dollars to clean up 35,000 gallons of conventional diesel for over three weeks. This translates to an $85/gallon production cost in addition to recovery of the product and excluding reprocessing. Has the vessel been carrying a synthetic fuel, this would have been a non issue and definitely making oil spill response clean-up unnecessary (http://www.angtl.com/pdfs/MarinePollution1.pdf). Further inclination on this line of thought is corroborated by The works of 'Lock, MA et al, 1981 which conclusion suggests that a short catastrophic synthetic crude oil spill would have a negligible effect upon benthic communities in stream riffles, as reported:

"...The response to the oil was minimal. Bacterial numbers and amounts of chlorophyll a were slightly increased on bricks treated with some of the oils. Numbers of diatoms and blue-green algae were generally about the same on treated and untreated bricks. The few significant differences in the responses of macro invertebrates indicated that there were no great shifts in community structure in response to the oil contamination. The study findings suggest that although a massive light oil spill into running freshwater will have an initial detrimental effect on fish and benthos, the long-term effects on the benthic flora and fauna encountered in the mid-channel of stony riffles with turbulent flow and a nearby refugium from which re-colonization could occur could be negligible. (Carroll-FRC)..."

This fact above shows that if the effect of synthetic fuel contamination, spill or pollution of the environment is not harmful to the ecosystem, then there might not be need for the oil spill response action.

The elimination of one of the most important factor of setting up the oil spill response process, by improved technology and from use of natural gas to produce synthetic (GTL) fuel, and the increasing production of same might simply spell doom for such environment sensitive industry. The question now is what becomes of the oil spill response processes in the light of increasing production of synthetic fuels that are acclaimed to be environmentally healthy, highly biodegradable and non toxic to the ecosystem? Should the oil spill industry be sustained for reasons other than environmental? This, the researcher will try to answer as we go along.

The globalisation efforts of multinationals across the globe such as the partnership of ChevronTexaco, NNPC and SASOL all representing United States of America, Nigeria, and South Africa respectively, is ongoing and is done as a business strategy for optimising their individual economic performance and at same time contribute to the solution of world energy demand. This merger on its own is creating challenges for the already established oil spill response industry- through environmental healing by promoting the conversion of gas to synthetic fuels like FT-diesel, which in turn will increase the probability of oil spills.

The poor focus on regulations and inadequate funding (Christopher M. P. et al, 2002) by government and other private authority since the decline of large spills had been responsible for environmental neglect (disregard for clean up operations) especially for small spills and this should not be the norm. One of the justifications for sustaining and encouraging oil spill response activities should be to prevent financial loss of a very scarce and highly needed energy product by ensuring investors satisfactions.

A caption in Environment times, (2005), On 'Secret Spills' shows that 70% of serious inland oil spills go unreported in United Kingdom and this constitute the biggest source of pollution in Britain. Among these pollutants are fuels and oil which constitute 17% of pollution incidents (EnvironmenT times, 2002). The most common, been diesel fuels. The Environmental Agency data also opines that in 2000 alone there were 6,215 substantiated pollution incidents involving oil, a 15% increase on the number of incidents in 1999 figures (EnvironmenT times, 2002). Presently, dispersed data everywhere shows that oil spill of diesel is on the rise. This trend is not likely to decrease due to growing use, transportation, and processing of refined oil product and synthetic fuels.

Efforts are constantly been made to prevent and eradicate oil spillage, regardless of what improvements are made, no transportation and process system is foolproof. There will always be spills associated with any form of land and marine process activities (Dickins, 1990). Given this facts, it is necessary to be prepared as possible for dealing with the inevitable.

In other to minimise the risk of pollution in our world today and compliance to legislature, it has become very important to have a well structured contingency plan towards oil spill response, especially from a management perspective. Every endeavour of humanity has a managerial aspect so does "oil spill response actions". This plan is expected to detail the expected line of communication, work to be done and major deliverables and allocate resources as required within a spill response scenario.

Aside from the mitigation of economic damage by spills, it has become very important to promote 'the spill response philosophy' to ensure the elimination of threat to life in all forms and to adequately comply with legislature. These are as important as the 'environmental plus' to warrant a systematic approach to tackling oil spill incidents.

It is now obvious that the solution to a global challenge creates other problems that require solutions and there is a continuous cycle of challenges and solutions emerging. The need to optimise energy sources and to control pollution from the production and use of synthetic fuels of natural gas origin should lead to a benefit for oil spill response process. This dissertation will attempt to x-ray the way forward for further research in the industry with respect to future synthetic oil spills.

1.5 AIM AND OBJECTIVES

The objective will be to provide a conceptual model of the 'response' life cycle with the aim of restructuring and re-engineering the response-process service of spillers and responders and adapting same to meeting increased likelihood of controlling and preventing spills of produced GTL fuels. This invariably will involve reorganising the implementation process of oil spill response actions.

The researcher will also be able to determine the most adaptive techniques, strategy, equipment and materials that suites the GTL product spills in other to be efficient and effective during clean-up with insight into the trade-off study of GTL diesel properties with respect to the local environments in comparison to conventional diesels.

The bottom line is to ensure continuity for adequate oil spill response industry and drive GTL project Planners, to review current oil spill response plan and strategy that is in place to give a more adaptive and effective approach as may be required by law to accommodate GTL product spill and adopt the reviewed implementation plan.

This dissertation is not intended to be comprehensive in detail, but to draw future researchers and industry operatives to benefits of rigorous planning, innovative conceptualisation, and utilisation of high technological devices and adoption of best management practice in oil spill response by evaluated prediction and forecasting capability.

1.6 SCOPE OF WORK

In the build-up of this dissertation, the research will attempt to focus on action plan for tackling GTL fuels spill within process production areas and surrounding environment. FT-diesel will in most case represent the synthetic oils during the course of this work and may be frequently interchanged with GTL diesel. The exposition will be in five chapters.

The effectiveness of response action in the events of spill is greatly dependent on the properties of the spilt oil; as such the conventional response equipment and materials elucidate these facts. It is then appropriate in the course of this work to highlight the properties of the Synthetic diesels in order to find the best way to respond in the event of spills. The researcher will also take a quick look at where oil spill usually emanate from as well as what leads to it and the damage they are likely to pose.

Looked upon as a Project, oil spill response involves planning, control, execution and co-ordination with planning as very crucial to the response action and overall performance. In chapter three, I will look at oil spill contingency planning and all necessary resources required in combating spills with the hope of outlining the best management practice in the industry via a benchmarking study. A look at all possible and practiced strategy and techniques known in spill science will also be highlighted in an attempt to model the best fit approach and equipment to combat spills of GTL fuels.

Chapter four will be crucial by showing the lifecycle approach to Oil Spill response Process as a systematic way of achieving success in the industry. In this chapter as well, the researcher will attempt to predict the fate and likely trajectory of FT-diesels in Excravos area, Nigeria by computer aided simulations. Moreover, I will trade-off the uniqueness of GTL fuels and suggest a better technique for clean-up. All in all, the work would have adopted proactive measures in response of oil spill at every phase of the project.

The dissertation at the end (chapter five) would have integrated Knowledge management, Project management, System Engineering approach, Risk management philosophy in the discussion along the whole body of work in coming to its conclusions on the way forward and giving recommendations for the enhancement of spill science body of knowledge involving GTL diesel fuels.

2.0 <u>CHAPTER TWO</u> (LITERATURE OVERVIEW)

2.1 <u>OVERVIEW OF GAS-TO-LIQUID (GTL) TECHNOLOGY</u>

Gas to Liquid (GTL) technology allows for the transformation of natural gas to liquid fuels and chemicals like methanol, Dimethl ether (DME), middle distillates (diesel and jet fuels), chemicals and waxes (EE/CEE Report, 2003). The technology is now been promoted for the economic benefit it offers in light of higher energy demand; higher quality of fuels produced; lesser environmental impact and monetisation of remote stranded natural gas occurrences around the world (FWI: GTL-LCA Synthesis Report, 2004).

The GTL technology involves the thermal oxidation of natural gas under controlled conditions to form synthetic gas commonly called syngas, which is mostly composed of hydrogen and carbon-monoxide. The syngas is subjected to reaction in a reactor in the presence of specific catalyst via the Fischer-Tropsch (FT) process to form slurry phase distillates and wax. The semi-product undergoes further processing in a Product Work up unit (PWU) via the Iso-cracking process to give various products like diesel, naphtha and LPG. See Figure 2.1 below.

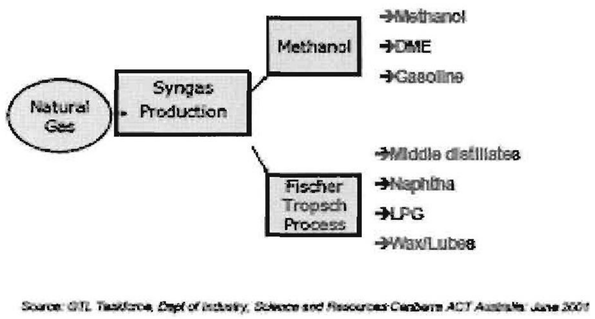


Figure 2.1 Products from Synthetic Gas reaction over specified Catalyst.
(EE/CEE Report, 2003).

The development of the Fischer-Tropsch (FT) process makes the difference in the conversion process and has been earlier utilised for converting coal to synthetic fuels. The FT process was one of the great technical breakthroughs of the 20th century having been perfected by SASOL of South Africa. Currently, SASOL has the most extensive experience worldwide in the application of FT technology on a commercial scale, resulting in huge improvements in synthetic fuel and chemical yields (www.Sasol Technology Research and Development.htm).

The Fischer-Tropsch (FT) process is one among many technology used to convert natural gas to synthetic fuels. A tested and proven GTL process includes Shell Middle Distillate Synthesis- SMDS (Gas to Liquids process) and the Syntroleum process among many others. In most patent licenced, it involves three major stages; which are

- Thermal oxidation of natural gas (Auto Thermal Reaction- ATR);
- The Fischer-Tropsch process (FT) and
- Product Workup Unit (PWU) otherwise called Iso-cracking. See figure 2.2.

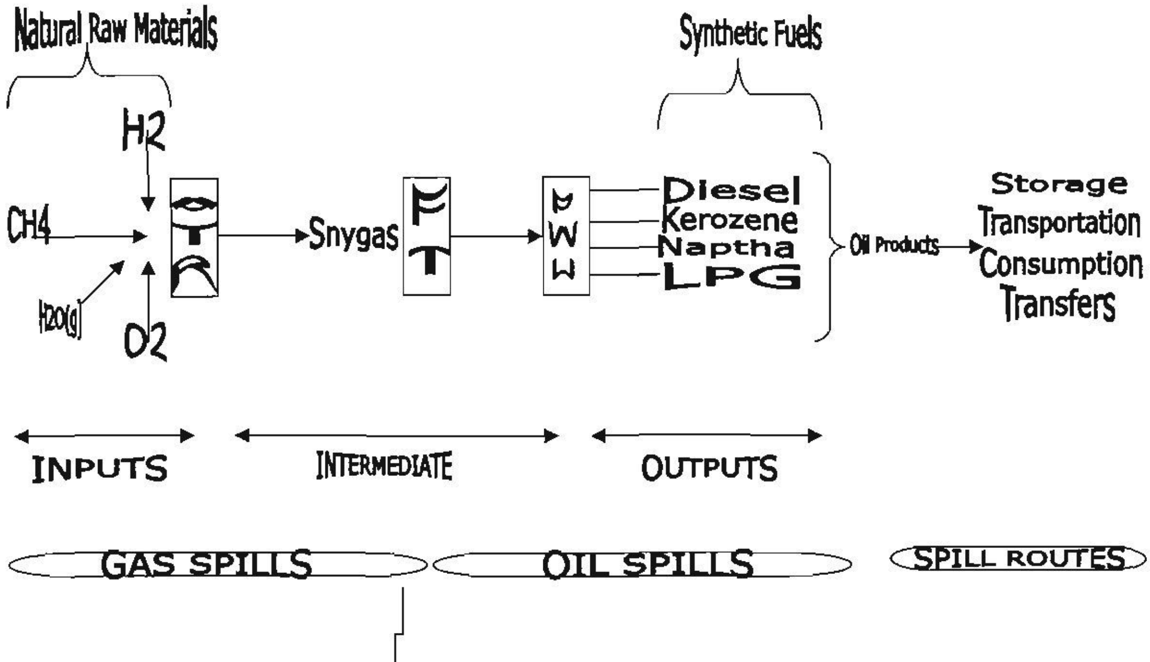


FIG 2.2 SYNTHETIC FUEL PRODUCTION PROCESS FLOW DIAGRAM IN RELATION TO SPILLAGE.

Along these routes of production (figure 2.2 above), oil spills do and can occur, most especially at each transfer window. Usually, the unset spillage may involve a gas leak which is not the focus of this dissertation. Oil spill is more tenable from the FT process onward to the PWU units (figure.2.3).

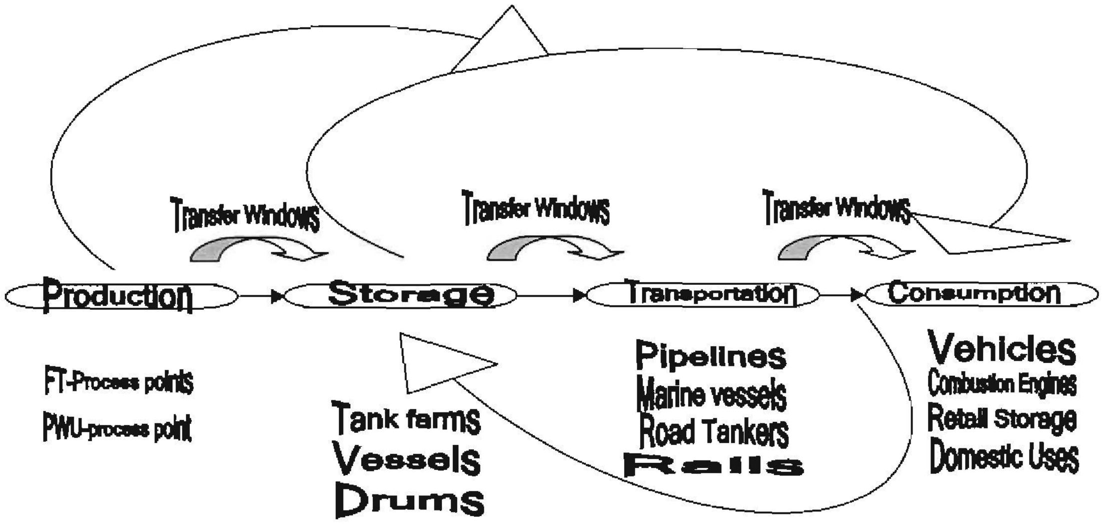


Fig 2.3 Synthetic fuel supply chain and spill route from production to utilization.

The Iso-cracking process which involves products separations' into individual fractions is most notable for likely oil spills situations. It is from this point that the spill-distribution-chain of the products is felt right from production, storage, transportation and consumption (figure 2.3). The diagram clearly shows the various links and scenario for each spill route from production to utilisation.

2.2 OVERVIEW OF OIL SPILL SOURCES, CAUSES AND EFFECTS

It is a known fact that oil spill is inevitable where oil or oily product exist. It has become a pointer then for oil spills to emanate from certain activities or areas which are either controllable or unavoidable.

Oil spill sources are numerous ranging from routine maintenance actions, accidents and incidents; industrial waste and sludge; municipal and constructional activities; oil leaks, land runoffs, (Nayar S et al, 2004) and natural seeps. A statistical break down of this estimation from NASA and the Smithsonian institution puts oil spillage volume at 707 million gallons into the ocean waters annually from differing sources (http://seawifs.gsfc.nasa.gov/OCEAN_PLANET/HTML/peril_oil_pollution.html).

The analysis of this volume has 'Down the drain' activities and 'Routine maintenance' as the biggest culprit (figure 2.4 and 2.5).

Figure 2.4 Major Oil Spill Source: Numeric Values in million of gallons.

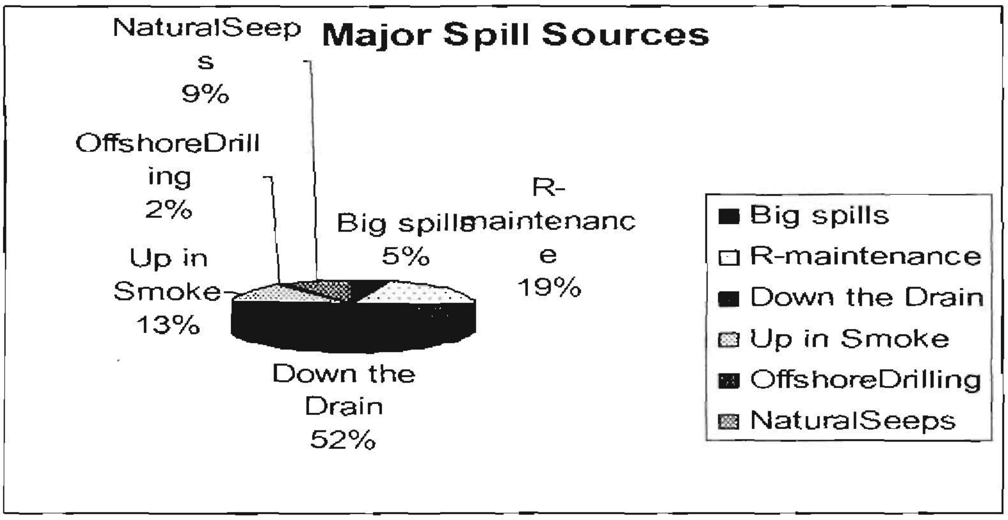


Figure 2.5 Major Oil Spill Source: as a percentage of Spill Volume.

The graph and diagram above clearly shows 'Down the drain' oil pollutant (runoffs) as 363 million gallons, been the largest source. Further evidence from 'Four Season synthetic, (2005) corroborates used-engine-oil that are improperly dumped as the highest single source of oil spills in United States of America water ways. The statistics shows 40% is dumped on the ground and down the sewer; 21% is thrown out with the trash, ending up in land fills; 6% is burned; 19% is reused for miscellaneous purposes and 14% is recycled (http://www.fourseasonsynthetic.com/green.htm).

Routine maintenance activities such as bilge cleaning and other ship and vessels operations release about 137 million gallons (19%) into navigable waters. The 'Up-in-Smoke' activities make up 92 million gallons of spilt oil (13%) from cars and industrial activities by the re-conversion of volatile organic components (VOC) by rain action into the ocean. The remaining figure of 2%, 5% and 9% is attributed to drilling activities; accidents and incidents; and natural seeps respectively (figure 3.2). Though accidental spills source account for 5%, there effects are devastating and extensive along the shoreline for miles and constitutes the largest volume of spills.

Aside from the above sources of spill, oil pipelines are seemingly overlooked source of oil spill worldwide (due to image and political issues). This is a critical asset to the oil and gas industry which accounts for most oily product mobility worldwide and also because of its degradable nature.

Pipelines are a long-established safe and efficient mode of transport for crude oil and petroleum products. They are used both for short-distance transport (e.g. within a refinery or depot, or between neighbouring installations) and over long distances. They make up an extensive network of cross-country grids stretching for miles in all kinds of terrain and are subjected to severe weather conditions doing what they do best. Pipelines are usually prone to stress and strain and as such do undergo wear and crack which leads to oil spillage.

The causes of oil spill are numerous and varied. It is for these reasons and more, that oil spill response was established in other to mitigate the consequence of such causes. A re-evaluation of CONCAWE (2006) report from 1971 to 2004 based on available data pinpoints five broad categories of causes as applicable to oil spills emanating from pipelines in European countries (Table 2.1).

2. Comparisons since 1971

	Number of Incidents			Percentage Gross Volume Spilled (m^3/yr)	
	2004	Average / yr 1971-2004	Percentage 1971-2004	2004 *	1971-2004
A. Mechanical failure	3	3.0	23.8%	34.5%	31.4%
B. Operational	-	0.9	6.8%	0	3.6%
C. Corrosion		3.6	28.9%	0	18.8%
D. Natural hazard	-	0.4	3.5%	0	4.1%
E. Third party activity	2	4.6	36.9%	65.5%	42.1%

* Volumes from one incident withheld for legal reasons.

Table 2.1: Major Causes of Pipeline Spills in European Countries.

CONCAWE which exist to measure oil pipeline performance annually does so to assist member countries and companies make informed decision in a timely manner to forestall pipeline integrity and prevent oil spillage. The statistical summary is also highly applicable to other regions of the world, especially where poor maintenance strategy, archaic technological devices and human activity go unchecked.

In Nigeria for instance and according to Mark Tran in Guardian Unlimited newspaper of 6th October, 2006, reports, **"...in a bid to get a share of the oil wealth, some have committed acts of sabotage by damaging pipelines so they can claim compensation or gain clean-up contracts for the oil spills"**; also to make quick profit from sales of scooped and siphoned petroleum product. Most times such actions have led to hundreds of death and a devastated environment. This trend is highly blamed on third party activities which arise sometimes out of incidents, accidental and/or deliberate actions of vandalisms. Statistics shows that in Nigeria, oil spill occurs as a result of corrosion of pipes and storage tanks-50%, sabotage – 28%, oil production operation – 21%, engineering drills, machine failures, poor loading and offloading operations, and ineffective oil well control – 1% (Nwilo and Badejo, 2001).

Other supporting views blame negligence, breakdown of equipment (gasket failure in flanges, loose bolts, ruptured seals, hairline crack); natural disasters (subsidence, flooding, landslides, earthquakes, tsunamis, hurricanes, thunder strikes); or deliberate dumping as causes of oil spills (Michael A, 2006). For instance (as reported by Michael

A, 2006), the oil spill incident of Exxon Valdez in prince William sound in Alaska in 1989 was primarily caused by Crew alcoholism and fatigue which in turn led to navigational error and subsequent collision with a reef as secondary causes.

It is evidenced from the example above that major oil spills are usually not caused by one single factor but rather a combination of events which culminate into disaster. These factors do include both failures which are preventable, and conditions which are not within human control. It is then proper to infer that the root cause of an accidental discharge of oil to the environment is near impracticable in the light of various influences. Analysing the cause(s) of oil spill severally posses a lot of challenges: either blamed on human errors or failure on the side of management/organisation (Oil Pollution report, 2006).

Examples of the human factors includes poor communication, use of drugs, alcoholism, improper equipment use, inaccurate computation, inattention of personnel, procedure error, complacency, fatigue, illness , sabotage, and non adherence to training procedure. The management on its side may fail to provide the necessary policies, procedures, equipment, personnel, supervision, training, field simulation, general funding for research and development towards oil spill prevention and control.

Another interesting cause of oil spillage is the reluctance on the part of many investigators to directly place blame on offenders because of liability concerns; and sympathy out of fear for lose of their livelihood. This trend actually encourages further spillage because previous investigations hardly indict anyone (Oil Pollution report, 2006).

Table 2.1 show the three most common factors responsible for pipeline oil spills. These are;

- Third party activity,
- corrosion (external rusting of pipes, internal CO2 attack of a girth weld with an unstabilised crude oil, and stress corrosion cracking); and
- Mechanical failure (material faults and constructional failures) with the highest records.

A lesser occurrence is Operational (human error and systems malfunction) and Natural hazards. This data which is extensive (1971 – 2004) should help decision makers in the oil and gas industry to focus on the areas that require improvement: people's behaviours, good maintenance culture and reliable facility and material utilisation.

The effects of oil spill are usually evident on plants, animals and the environment at large. The degree of impact to the ecosystem is usually greater with higher concentration of dissolved and particulate oil. Such effects of oil spill are either lethal or sub-lethal: cursing deaths or permanent disability in plants and creatures of the air, sea and land. These effects decreases with time with a declining concentration in the environments thought some effects are irreversible.

In plant community, the effects of freshly spilt oil may cause acute impacts which may range from: increased algal growth; slower growth rate; lower fecundity; localised tissue rupture; premature expulsion of larvae; and excessive mucous production (NOAA. 1992). The work of Nayar, S et al (2004), has also shown that periphytic algae undergoes decline in biomass size with exposure to diesel spills over three days period. This he said occur by affecting the size of the 'chlorophyll-a' and cell number of the biotic community. Photo-inhibition of periphyton also occurs due to high irradiance (Nayar, S 2004). Suppression of phytoplankton has been reported with petroleum hydrocarbon concentration exceeding 1.5mg/l. other damage to terrestrial plants includes leaf drops, inhibited seed germination, and deaths (CONCAWE, 1996).

Animals have been shown to exercise the ability to detect and avoid oil spill and other petroleum hydrocarbon in their environment (NOAA, 1992). Oil spill impacts affects creatures in three major ways, by direct surface fouling, inhalation, and ingestion.
Surface fouling otherwise termed oiling can cause severe irritation in animals. It is also a risk factor to the thermoregulatory capabilities of animals and in some case reduces the feeding efficiency in them.

Oiling effect also causes change of taste of plant and animal product within the food chain. Continuous ingestion of such product can lead to bioaccumulation in the tissues of animals and may lead to diseases or death over time. Tainting is another effect on organism by spilt oil which alters their natural colour and this influences taste.
In some cases, spilt oil contains lots of volatile organic components (VOC); these invisible gasses are toxic and may have a critical consequence if inhaled in large volume

by animals. VOC affects the respiratory system causing asphyxiation, drowsiness, impaired vision, fainting and in some cases death within few hours.

The effect of GTL fuels would be relatively less harmful to the environment, given there properties. There most impact is likely to be a threat to the aesthetics and general landscape of the environment at large. The major product from synthetic production would most likely be diesel. This focus invariably orients us to the more likely consequence during spillage. CONCAWE report on 'Gas Oils' clearly shows that conventional diesels can remove fats from the skin and prolonged exposure can result in drying and cracking of the skin in humans; irritation and dermatitis (CONCAWE., 1996). In some severe cases of exposure, it may lead to oil acne and folliculitis and less frequently, the development of warty growth. This effect may be expected from GTL diesels, probably with lesser consequence. Even so, this aspect needs sound scientific investigation.

Statistics on adverse effects of diesel spills around fresh water environment is relatively scarce, though fishes and waterfowls have always been most affected. Nonetheless, spillage of diesel fuels into marine environment has been established not to be severe. However, direct toxicity and fouling of marine organisms, including insects, crayfishes, birds and marine mammals may occur (CONCAWE. 1996). On the other hand this is less likely to occur with spillage of GTL diesels into aquatic environment.

2.3 PHYSICAL - CHEMICAL PROPERTIES OF GTL FUELS

The properties of oils influence their fate when spilled, and determines the proper equipment to use during clean-up. It also determines the strategy to adopt during containment, recovery and disposal.

The products from GTL plant range from diesel, kerosene, naphtha, LPG, lube oil and waxes. These products exhibit certain unique characteristics which makes them one of the cleanest fuel ever developed and for its efficiency and environmental merits. Among these products, diesel is the most researched and produced to date in the synthetic fuel portfolio and more likely to be spilt. This diesel is under the general groupings of 'gas oils' which are variable mixtures of hydrocarbons and their carbon number range from

C_{11} to C_{25} and boiling point range of 150˚C to 450˚C (CONCAWE. 1996). The most predominant alkanes among the diesel been nC_{15} to nC_{17} (Mclaren, 1985). Generally, the principal products of diesel fuels are the automotive fuels for diesel engines; this includes: Automotive gas oil (AGO), automotive diesel fuels (DERV), Diesel fuels No. 2, and Rail road engine gas oil (CONCAWE. 1996).

The FT-diesel is on the spot light for the GTL fuels and will be compared with other conventional diesels in the course of this elucidation.

GTL diesel is (straight and branched chain) paraffinic in nature and contains negligible aromatics, cyclo-paraffins and polar species (CONCAWE. 1996; Nannen, 2003). This results in significantly reduced emissions from diesel. The fuels is water white, odourless and has a superior ecotoxicity and biodegradability characteristics compared to other clean diesels on the market (Nannen, 2003). GTL diesel has virtually no sulphur and has a relatively higher heating value compared to other conventional fuels and produces negligible soot (See Table 2.2 below).

Experimentation with FT-diesel has shown simultaneous exhaust emission reduction of 50% for particulates and 20% for NO_x in Volkswagen diesel vehicles compared to standard diesel (Nannen, 2003). GTL fuels (diesel and naphtha) are so regarded as ideal hydrocarbon fuels for use in cell vehicles, due to its low sulphur content and relatively high hydrogen fraction.

The presence of mostly saturated hydrocarbon makes it less toxic and more likely to have a lower boiling point range than other diesels ever produced (Warner et al, 1983; Clark et al. 2003) also this character makes it more biodegradable than conventional diesels with higher carbon member and bonds (Pitter and Chudoba, 1990 in Nannen, 2003). It has been shown also that FT-diesel has higher and very good cetane value (CN>80) and low density compared to conventional diesels (Clark et al. 2003). Its lighter nature as seen (Table 2.2) would likely cause quicker evaporation when spilt.

In a more practical sense and based on the chemistry of GTL diesel, suffice the researcher to infer that GTL diesels are among the least toxic and most biodegradable fuels in production and as such environmentally friendly and ecotoxicologically benign. This fact is supported by research findings by Clark et al (2003) where no toxicity or adverse effects were observed on *P. promelas, D. magna,* and *R. subcapitata,* when tested with SMDS-2 diesel (FT-diesel) > 1000mg/l.

Conventional fuels on the other hand has a wider boiling range due to higher aromatic compound, they are also more toxic, richer in sulphur and particulate matter and has presence of metallic radicals like lead, vanadium, and nickel. This in turn causes corrosion when their concentration is above 2ppm in the fuels; moreover, conventional diesel produces soot when burnt due to the polar species and sulphur they contain (CONCAWE. 1996; Nannen, 2003).

COMPARATIVE PHYSICAL-CHEMICAL PROPERTY OF CONVENTIONAL AND FT-DIESELS					
ATTRIBUTE	Units	AGO No. 2 Diesel	FT-DIESEL GTL	FT-DIESEL Typical GTL	FT-DIESEL S-2 Synthetic Diesel
Physical State		Liquid	Liquid	Liquid	Liquid
Colour		Light Brown - Yellow	Water White	Colourless	Colourless (L0.5)
Solubility		Insoluble	Insoluble	Insoluble	Insoluble
Odour		Strong paraffin	odourless	Odourless	Odourless to mild paraffin
Density @ 15oC	g/ml	0.82 - 0.86	0.775	~ 0.78	0.771 (API: 52°)
Boiling range	°C	160 - 390 °C	160 - 382	155 - 375	(160 - 350) °C
Flash Point	°C	56 °C		> 55	51.5 – 60; 64 °C
Pour point	°C	-5			-18. 0° C
Viscosity @ 40 oC	cP	2 - 4.5	1.9 - 4.1 cP	2	2.1 Cst
Vapour Pressure	psi	ca 0.4			< 2psi @ 20 °C
Vapour Density	air = 1	4.5			> 1
Heat Value	MJ/kg	42.6 - 43.04	43.67	47.1	43.836
Auto Ignition Temp	°C	225			257 °C
Cetane (CN) No	Units	54	81	> 75	>74
Aromatics	% w/w	18.1 – 20.3	< 0.04	< 1	Not detected
Olefins	%w/w				Not detected
Saturates	%w/w	46 – 54.1			>99
S content	% w/w	0.025 - 0.05	< 0.001	< 0.005	Not detected
C content	%w/w	85.9	85.6		NA
H content	% w/w	14.1	14.4		
Carbon Residue	wt%				Not detected
Ash	wt%				<0.001
LEL	vol %	0.6			~0.6
UEL	vol %	7.5			~4.7
SOURCES		CONCAWE., 1996 Nannen, 2003 SOTS., 2003	Nannen, 2003	SasolChevron, 2003	Syntroleum Corp., 2004 ICRC & SC., 2002

Table 2.2: Comparative Physical-Chemical Properties of Conventional & FT-Diesels

The properties of this GTL fuels contribute less to the level of impact on the environment and would determine the degree of risk analysis involved in contingency planning and during mitigation when spilt. This is why spill practitioners must understand the physical-chemical parameters that are crucial in spill science such as the following: Density (specific gravity), Pour point, Vapour pressure, Kinematic viscosity, diffusion coefficient, Surface tension, flash point, Boiling range and its auto ignition temperatures.

The knowledge would help in effectively choosing the right tools for clean-up and adopt the best strategy during response.

2.4 FATE AND BEHAVIOUR OF OIL SPILLS OF SYNTHETIC ORIGIN

Reviews of literatures have shown that greater percentage of spills end up into the drainage and subsequently to the sea. The spillage of oil takes place both on land and on water, though the later seems to be most frequently discussed and documented. This is as a result of the extent of environmental impact and spread associated with water transport.

The source, location and mode of transport are strongly responsible for the skew of spill activities. Most oil related facilities and Terminals are located off-shores and on the fringes of the ocean to land area. The GTL plants are no exception to this orientation, such as the Oryx GTL plant in Ras Lafan Qatar and EGTL plant (under Construction) in Excravos Nigeria.

GTL products would undergo certain fate when spilled into the marine environment. The characteristic properties of the synthetic products and by-products are very important to be known, because they aid in determining best fit contingency plan, response, and clean-up action (CONCAWE.1983a;Cekirge and Palmer, 2001).

A combination of the characteristics of spilt oil and the mode of movement is paramount to a successful 'spill response' (French, 2001). The understanding of the fates that oil undergo aids responders to carry out effective natural resource damage assessments, cost benefit analysis, and adequate contingency planning.

Spilt oil undergoes various forms and process in the environment. The processes includes: spreading, evaporation, dispersion (entrainment), emulsification, dissolution, sedimentation and degradation. These processes usually affect the degree of weathering of spilt oil especially on water (CONCAWE. 1983a). Other workers (Cekirge and Palmer, 2001), considers additional processes such as drift, stranding, adsorption and desorption; and photo-oxidation. More recently, 'clay-oil flocculation' is gaining acceptance as a natural cleansing process worthy of embrace (Bragg and Yang, 1995).

Among these cleansing routes, spreading, evaporation, dissolution, degradation and photo-oxidation are the most likely influence on GTL fuels when spilt on water because of their lighter weight and content, whereas on land such product would probably suffer quick absorption by sand and soil into pore spaces. For example, the research work by McLaren (1985) shows diesel spills undergo quick penetration into sediments and are retained as such. In some cases, it gets down to the water table and is easily moved by tidal cycle and changing water table levels. Diesels and No.2 fuels have been known to be persistent in the environment and have long time contamination potentials to the intertidal resources and they also impact subtidal fronts by dissolution, mixing, and absorption onto suspended sediments (NOAA. 1992).

GTL fuels like diesel would spread very fast due to their light weight and most times form sheen on water. This spreading behaviour is dependent on the wind power, under water current, density, Kinematic viscosity and on the spreading coefficient (CONCAWE. 1983a). FT-diesels are known to have very low pour point as such would generally be less than the ambient seawater temperature. This is an important parameter to its ability to spread with ease and remain liquid even in very cold environment. The quick spreading quality of such diesels creates tremendous impact in a short time around the spilt area and can easily permeate into tissues within the ecosystem especially into sediments. Moreover, being able to predict surface spreading is important in estimating weathering processes and for designing slick containment response (Cerkirge and Palmer, 2001).

GTL diesels like the conventional diesels would suffer the most important weathering process: evaporation. Its light nature makes it even easier to get rid of from the environment after a spillage, as such, it does not persist on water unless when spilt on other sensitive environment like land, marsh, and beaches. Evaporation has been documented to remove 100 percent of gasoline spill from the environment within a very short time (Breuel, 1981a-b; NOAA, 1992). This trend would reasonably be expected for diesels of GTL origin to at least, spilt-oil-loss of up to 50 percent or more; given that 20-30 percent of most oil is lost to evaporation within 24 hours of spillage (CONCAWE. 1983a, NOAA. 1992). Evaporation rate of diesels would be affected by the diesel composition, temperature of the environment, spill area, wind speed, roughness of the sea, solar radiation, and slick thickness.

Dissolution of diesel occurs after evaporation of the lightest components due to vigorous mixing. This makes the components of GTL diesels slightly susceptible to solubility in seawater due to the high presence of paraffin in its makeup (CONCAWE. 1983a). This process usually affects the lighter short-chain components (Cerkirge and Palmer, 2001) like alkanes and furthermore, dissolved volatile components near the surface, in a well mixed zone will subsequently be subject to evaporation. Although alkanes have been observed to show less solubility than aromatic hydrocarbon in general (NOAA. 1992), as such are less likely to pose toxicity risk to aquatic organism within the water column.

Fresh water environment poses a different challenge, where dissolution of GTL diesel components would be expected to be higher relative to seawater. This might be expected due to the fact that solubility of hydrocarbon components is higher by 70% in fresh water than in sea water (Sutton and Calder, 1974 in NOAA. 1992). With this fact in mind spillers and responders should expect greater impact in fresh water environment. Dissolution generally is affected by salinity, temperature, Kinematic Viscosity, and surface area in contact with water.

It has been established that degradation of oils take place through photo-oxidative processes which is the reaction of volatile components with OH radicals in air and bio-degradation of diesels oils is quickly promoted by aerobic conditions (CONCAWE. 1996). In anaerobic conditions, the oil may become persistent in soils and sediments. Degradation is accelerated by bioturbation or re-suspension process which re-introduces oxygen. The products formed from photo-oxidative processes during degradation are soluble and more amenable to bio-degradation.

The major components of GTL diesels are paraffin; these have been shown to degrade very quickly (CONCAWE. 1983a). The light weight of GTL diesels and its implied fast spreading rate during spillage should create a greater surface area for the bacterial action which speeds up the degradation rate (Cerkirge and Palmer, 2001). Dispersion of the oil droplets in water also increases the oil/water interfacial area by 3 to 4 times which enhances the rate of degradation (CONCAWE. 1983a).

Research has shown also that alkanes are metabolised to carboxylic acids by oxidation in aquatic organisms and such products are incorporated into the lipid pools in the organism (CONCAWE. 1996). This action involves the breakdown from one form to another and is easily excreted. Since GTL diesels are basically alkanes, they will be expected to share the similar fate.

3.0 CHAPTER THREE (MANAGEMENT STRATEGIES IN SPILL RESPONSE)

3.1 SPILL RESPONSE CONTINGENCY PLAN [BMP]

Planning is crucial in achieving effective execution in the event of emergencies. The possibility of an oil spill occurring informs a systematic and predetermined set of outcomes which is translated into a document commonly known as a contingency plan. In oil spill quarters, it is also referred to as preparedness, prevention and contingency plan or a discharge prevention and response plan (US CFR-OSPR Act, 1991). Moreover, some may refer to it as 'emergency response and pollution prevention plan' (Decker, 2003).

A spill contingency plan (SCP) is expected to be developed for all major resources for the production and utilisation of GTL fuels. The link is from the GTL plant, to Storage tank farm, to Transport vessels, and to Retailing outlets. These routes of spills should have a contingency plan known as follows:

- Terminal facility response plan for: GTL plant
- Oil storage response plan for: Storage tank farm
- Vessel-specific response plan for: Transport vessels
- Site-specific response plan for: Retailing outlets

Decker, (2003) clearly supports an integrated contingency plan (ICP) for the reason that it saves time and cost effective for facilities that must manage multiple emergency response planning requirements.

Spill contingency planning approaches is important. It allows control and mitigation of the level of inherent risk associated with oil spills. It is developed after a risk analysis is carried out and an established eventuality noted and provided for by the contingency plan as a control measure. This act of planning allows us to work out general approaches and procedures to deal with a variety of incidents (CAIA-GC CAER an 2, 1998:2).

A GTL facility should have a response coordinating office known as 'Oil spill response centre' which should act as a first point of contact in an emergency involving oil spills. This office will serve as a project office with dedicated phone number, e-mail address, pagers, electronic and digital notification devices, and other general communication gadgets. An up coming GTL plant like EGTL plant in Nigeria would require such a centre, manned by a facility response coordinator or supervisor as the project manager, well trained responders and with a well defined facility response plan (FRP). This structure will allow for

- ❖ Efficient and optimal utilisation and mobilisation of resources during call-outs.
- ❖ Coordination of contingency planning and preparedness outlines
- ❖ Defining and proscribing clean-up strategies and techniques
- ❖ Defining manpower requirements and coordinate drill exercises
- ❖ Providing advice and support to On-scene Coordinator or remedial project managers during responses and
- ❖ Carrying out surveillance, predictive, and proactive measures to avert spills.

Hix-Mays (1995) cites that a response office should acts as a communication centre and a point of contact for all pollution incidents reporting and also functions as a 'Response Team Office'. An excellent account of duties and responsibilities of 'response team personnel' and its organogram has been given in Levine (1988).

The content of an ISCP or SCP entails detailed requirement both functional and technical in nature. These specifications and elements are fundamental to a well drafted plan fit-for-purpose. They include but not limited to the following:

- ❖ Facility and asset description of the spatial area covered by the plan: storage, loading and process zones.
- ❖ Detailed emergency response procedures: evacuation, first responders, equipment deployed information.
- ❖ Spill potential summary: inventory of material stored on site, potential hazards, possible release scenarios and calculation of worst-case events; identification of sensitive receptors and outlined best response activities to be taken.
- ❖ Outlined annual schedule of training for drills, tabletop exercises, test of notification procedures and general class room instructions.
- ❖ List of and identification of offsite third party contractors (where one cannot be recruited in house); and associated responsibilities, contact details with alliance agreement proofs.

- List of response equipment available to ensure effective removal and mitigation or prevention of discharges.
- Must delineate the decision-making procedures for trade-off elements such as dispersants use.
- Must describe the integration of similar (vessels, storage, offshore and onshore facilities, pump stations, etc) emergency plan at a wider level.
- Should contain a detailed ESI map showing
    - prioritised ecological systems to be protected around the facility,
    - Containing the response capability required to protect, rescue, and rehabilitate the biota elements likely to be impacted.
    - Include the process of obtaining such resources in events of spills.
    - Identify and establish priorities for protecting the sea and wildlife.
    - Provide a mechanism for timely identification of protected priorities.
    - Provide information and procedures necessary to respond to discharges that could harm sea-life and wild-life.
    - List of identified methods that will minimise adverse effects on biota
    - Contain plans for acquiring and using response capabilities.

Requirements for evaluating the integrated work out process must be defined for the ESI within the SCP (Hix-Mays 1995; Nwilo & Badejo 2001, Decker 2003).

Other elements of ISCP/SCP should include:

- Spill detection expertise: description of leak detection and alarm systems, devices, equipment, procedures and threshold sensitivities.
- Description of communication systems and procedures by establishing hierarchal structures and chain of command.
- List of all available response personnel, responsibilities and contact details and acquired competencies.
- Identification of logistic resources: methods to transport personnel and equipment to site or transportation services available; identification of accommodations for emergency responders during call-out.
- Advance provision of spill clean-up packets for responders: boilers, suits, hardhats, gloves, foul weather gear, dust mask, goggles, cameras, recorders, binoculars, overall clothing, office supplies, first aid kits, and others.

- ❖ Prescription of post-spill review and guidelines to response planning standards updates (Levine 1988; Hix-Mays 1995; Decker 2003; PS/BCOSTF, 2003; U.S. EPA 2004).
- ❖ Owens (1990) also advised for inclusion of standardised reporting template and/or formats and list of approved terminology to be developed and included in the SCP. This will offer a most effective method of documenting a spill incident and gathering information.

It is advised, for in-depth break down of contents and more on SCP to consult PS/BCOSTF, 2003 (www.oilspilltaskforce.org/docs/cplaneelements.pdf) and U.S. EPA 2004 (www.epa.gov/oilspill/pdfs/chap6.pdf) for further study. Observations have also shown that a good drafted SCP leans on EIA study and SEIA report for sound content.

A SCP outlines the set of instructions that should be taken before, during, and after oil spill. It looks at possibility of what could go wrong and prepares in advance to mitigate, control and possibly prevent the spill from happening. It can be said to be a cost effective defense for dealing with eventuality. Moreover, it is important that SCP should be flexible enough to accommodate annual reviews and updates in other to facilitate accuracy, completeness and allow for establishing evidence of full implementation. SCP should readily provide clear, but, detailed information for responding effectively to spill.

3.2 SPILL SURVEILLANCE AND TRACKING PROCESS

Surveillance and tracking is an act of assessing the chance and extent of impact of spilt oil in the environment. There are basically three ways of carrying out this venture:

- ❖ Road driven vehicle and road walk inspections
- ❖ Water vessels surveillance by use of boats and
- ❖ Aerial flight over zones of likely impact by use of aircrafts.

There are limitations to the use of the road driven vehicles and water craft to carry out effective reconnaissance study of the area, at best a combination of any two or all gives the most efficient data gathering approach for studying spill behaviours. The practice allows responders to

- ❖ Locate oil sheens and slicks and source of emanation

- Estimate oil size, colour, volume, coverage and thickness
- Allow easier prediction of spill trajectory and fate
- Identify shoreline section for protection
- Makes for quicker and well informed decisions on clean-up operations
- It facilitates proper logistic planning of resources and
- It promotes adequate monitoring of spill situations.

The focus of this strategy is based on visual observation made by the personnel either with the naked eye or by help of discerning devices onboard the vessel, land vehicle or aircraft. This response strategy is a continuous method that facilitates decision making before, during and after a spill event. The spotlight of this stratagem is to

- Carryout ground inspections: These stops are made to provide official examination opportunity and to check for buried oil {extent of penetration or sinking} (Owens and Henshaw, 2002). It allows for ground spot checks to be conducted at intervals by drilling monitoring wells for sediment sample collection and analysis.
- Aerial mapping of regions: This involves geospatial overhead photographs taken of the area with the greater aim of predicting its trajectory and likely route of impact. Another technique involves Direct Visual Observation (DVO) and
- Video documentation: This creates images over time that is used for evaluation.

Ground-Inspection activities in surveillance and tracking process, involves use of measuring kits for quick field analysis. A lot of on-site analysing kits have been developed some of which includes the following:

- The surface sampling kit: used to collect oil sample from water surface for subsequent physical analysis and also used to determine the thickness of the oil.
- The person-portable oil analysis kit is capable of measuring density, viscosity, water content, dispersant effectiveness, and emulsion breaking effectiveness (Lambert et al, 1994).

The importance of on-site analysis at an oil spill site is to provide timely details on what potentially will happen to the oil and the environment. This will help in making quick decision on operational resources for clean-up.

The top practice of surveillance and tracking has been seen to be the use of aircrafts of differing kinds for monitoring and appraisal. This trend will continue now and so much into the future because of the advantages it has:

- close contact to the environment, especially when the access is remote
- quality of manoeuvrability of craft while tracking oil slicks
- swift mobilisation to site and heavy lift potentials
- capacity for long time flight for monitoring oil fate on sea
- its ability to act as a navigational aid during resources deployment and
- Platforms for hosting spill detection devices and executing clean-ups (O'Hagan, 2006).

Historical spill events and advancement in technology has buttressed the inadequacy of still camera photography and VHS documentary. They are insufficient for proper and effective spill monitoring and tracking management. The focus should lie in the use of remote sensing devices in controlling and tracking (Okoro, 2004). Although, the use of remote sensing from aircraft is relatively common technology, their adaptation and use of satellite remote sensing in monitoring spill and possibly predicting the spill behaviour is still far from effective for real time online purposes (Salt, 2004).

The remote sensing devices or sensors are usually mounted onboard a surveillance and tracking aircraft and some are hand held also utilised in vessels on sea for closer proximity. These sensors include but not limited to the following:

- Radar
    - Side Looking Airborne Radar (SLAR)
    - Synthetic Aperture Radar (SAR)
- Focal and Plan Detective Cameras
    - Thermal Infra Red (TIR)
    - Mid Infra Red (MIR)
- Ultra Violet (UV) Cameras
- Visible Video: Global Positioning System (GPS)
- Interferometer
- Microwave Radiometers (MR)
- Laser Flourosensor (LF)
- Thickness Sensor (TS) and
- Satellite Radar and Satellite Visible

Side Looking airborne Radar, {SLAR}, IR / UV and optical, remain the most widely used sensors for tracking oil spills. A number of very sophisticated systems give a high degree of resolution and image accuracy. They provide a relatively costs effective solution to the problem and is invaluable in guiding either dispersant systems of recovery vessels to the heaviest concentrations of oil (Salt, 2004). Laser Flourosensor are best used for night vision and fog work. Thickness sensors are tailored unsurpassed for thickness and volume measurement and experimentation at sea. Moreover, SLAR, SAR, IR/UV, TS, and LF are fully operational and works well (Okoro, 2004).

The GTL nations like Malaysia, Qatar, and South Africa need to do more than their present capabilities with aerial surveillance. Available statistics shows Malaysia has two aircrafts with SLAR and Visible sensors, whereas South Africa has only one aircraft utilising visual observations. Countries like USA, Canada, Germany Sweden, Netherlands and Portugal have extensive capabilities in oil spill surveillance and tracking (O'Hagan, 2006; Table 3.1). Qatar and Nigeria need to acquire these capabilities being the second generation GTL nations in view.

Summary of Oil Spill surveillance capability of various countries

- Germany – Two aircraft equipped with SLAR, IR/UV, low-light level video cameras, MWR, LFS. Envisat ASAR, Radarsat 1
- The Netherlands – One aircraft equipped with SLAR, IR/UV. Envisat ASAR and Radarsat 1
- Sweden – Three aircraft equipped with SLAR, IR, UV, Visible photographic and video equipment. Envisat ASAR and Radarsat 1
- Malaysia- Two aircraft equipped with SLAR and visible sensors
- South Africa – One aircraft utilising visual observations.
- Portugal – Five aircraft equipped with SLAR, IR, UV and MWR
- Norway – One aircraft equipped with SLAR, IR/UV, digital cameras. Envisat ASAR and Radarsat 1.
- USA – Various aircraft and helicopters equipped with SLAR and IR
- Canada – Various aircraft equipped with SLAR, IR/UV, AIS System, Digital Camera and video system, LFS. Radarsat 1 and Envisat ASAR

Table 3.1 Summary of Oil Spill Surveillance Capabilities of Various Countries (Curled from O'Hagan, 2006)

3.3 SPILL CONTAINMENT AND CONTROL TECHNIQUES

The establishment of a GTL plant would allow for drafting and development of a contingency plan which will inform monitoring and continuous evaluation of the process zones and surrounding areas. In the advent of a spill occurring, certain corrective approaches have to be adopted. These methods are many and diverse in scale depending on the impacted areas or environment.

The present GTL plants existing and under construction (like in Nigeria) are on the fringes of the ocean from land. This facility is usually among terminal assets in a given location and typically surrounded by sensitive priorities and ecosystems. Examples of these priority includes, human settlements, marshlands, swamps, mangroves, estuary, brackish and fresh water streams, beaches, docks, harbours, tourist sites, and marinas.

The first thing that comes to mind when these resources are under siege is to control the source of discharge or leak were feasible to minimise impact to vital areas by nip-it-in-the-bud principle. The second step would be to contain the spill (FT-diesel) as quickly as possible near the source to avoid rapid dispersion and spread given the nature of FT-diesel fuels.

It has been established in earlier chapter, based on density, viscosity and coefficient of dispersion that FT-diesel will float on water and will move very fast. This calls for prevention and control of its spread. Containment of spilt diesel would be expected to be easier on land area relative to sea (Owens, 2002). This is so because the spreading factor on water is more dynamic and this creates a higher level of uncertainty and unpredictability comparative to land where it is known to be slower.

Spills on land usually moves down slope and would be contained naturally in creeks, ditches, streams, rivers, and due to the difference in surface level, diesel spill would be collected in depressions forming pools on land (Owens, 2002). These collecting points could be lakes, ponds, open surface wells, holes and trenches. These natural forms of containment would allow for easier recovery of the spilt diesel either for disposal or re-use.

Human made response methods for containment and control of impending spill would include the following:

- Erection of barriers
- Construction of berms and dikes
- Digging of trenches
- Use of materials and
- Configurations (CONCAWE, 1983b)

The appropriate action would be to curtail the movement, thereby making recovery easier. Moreover, Owens and Douglas (1999) have shown a systematic strategy of further controlling the spill. These are

- Identification of proper interception points (control sites),
- Pre-staging of equipment to establish control (near source principle) and
- Pre-deployment of equipment to institute containment (use of booms).

From a socio-economic stand point, the spilling of FT-diesel on land would have a colossal impact on human-use activities and resources. This can be visualised in a populated area where the spill has occurred and would require immediate clean-up especially were the risk of pollution to fresh water streams and fire outbreak is eminent to dry vegetations, trees, farm lands, and settlements. Owens, (2002) believes that the presence of civil authorities (police and army) is essential around such scenes, in other to ensure site security for both responders and the general public and I cannot agree any less.

On water, the story is a bit different due to the variable forces in action. The best way of controlling the diesel spilt is by use of booms which comes in various size and weight. Booms are used in a variety of situations especially in relatively calm sheltered waters at oil installations or as a protective barrier on rivers and estuaries.

Booms practically increase the thickness of the oil layer which facilitates easy removal by use of equipment or burning. Various kinds of booms exist. Most are known by their function (protective, containment, burn support, and controlling), environment of use, size, and its mooring style. They are now been made of neoprene and polyurethane materials; also designed to improve their reliability, deployability, transportation and cleaning (Salt, 2004). They are:

- Curtain (skirt) booms and fence booms: they may be either flexible or rigid type booms with the flexible been spring loaded or inflated. Examples are flexible curtain-type booms and rigid fence-type booms.
- Fire booms
    - Fireproof booms: they last for multiple operation days and are made of highly durable materials. Examples are Stainless steel booms and Water-cooled booms.
    - Fire resistant booms: they last one operational day and under go degradation when subjected to intense heat and flame during in-situ burn operations (US-Federal Register, 2002b).
- Moored booms: they are mostly used in the open sea where the wind and current power is higher. Examples include Anchored booms, free floating booms and drogue supported booms.
- Sorbent booms: they are used to soak up small escaping oil on water behind a primary boom. It acts as a backup boom and guards against the presence of oil sheen near shore. Examples are natural sorbents and artificial sorbents. Other sorbent materials used for oil mop-up includes pads, rolls, pillows, snares, granules and others.

Conventional booms in use are now been manufactured with boom vanes for easier deployment in fast flowing rivers and are effectively used to protect sensitive areas and facilities by deploying them in such a manner that it gives optimal benefit. Examples of the deployment styles include:

- Exclusion booming
- Diversion booming
- Sorbent booming and
- Containment booming {Breuel (ed.), 1981a}.

Booms are configured in various ways depending on the objective(s) of the responder. The influencing factors towards recovering the oil are usually weather trend, how quickly the clean-up is expected to last, location of resource priority and available clean-up equipment. These unique arrangements are often associated with booming styles. The configuration approaches are:

- Cascading configuration
- Chevron ('V') configuration
- 'U' configuration
- 'J' configuration
- 'W' configuration,
- Paralleled shoreline configuration.

A lot of other booming arrangement can be achieved. This usually depends on the environment, length and quantity of booms available and the expertise of the operator on site.

Booming activity has been seen to be important. Alternatively, historical documentation and records have elucidated the use of natural barriers to contain spills like in the use of logs and heavy shrub vegetation and so on (Owens, 1999). This may be effective in some cases especially, where very thick oil is spilled. In the case of diesels generally, it may not be good enough unless they are of absorbing nature. It is also important to note that which ever case it is, this measure is only temporary because it only succeeds in slowing down the spill and not necessarily containing it. This buys time for apt and effective response.

Other means of control would be use of sands of very fine particle size in preparedness on very small spills of diesel origin like GTL diesel. Such stock can always be kept near-by in drums and in proximity to high risk zones. This approach absorbs the spill and makes it easy for collection and removal. It can be most effective on paved surfaces like in process zones, at homes, diesel retail outlets and on tarred roads.

3.4 SPILL CLEAN-UP: RECOVERY AND DISPOSAL PROCESS

The containment and control action of spill is simultaneously followed by recovery which may involve removal, remediation, disposal or 'burn'. This clean-up process can either be by use of equipment that collect the oil into a temporary storage or by means of physical gathering, use of chemicals, In-situ burning, and/or no-action stay on the spill. The 'no-action stay' (natural recovery) allows only the natural forces to remove oil from the environment at its own pace. This is usually considered when there is no environmental and net cost benefit to owner(s) and stakeholders; especially in the open sea. Furthermore, the natural recovery process the environment undergoes when spilt with FT-diesel is dependent on the property of the oil and the weathering characteristics. This fate can be modelled to establish the likely rate of recovery by analysing the oil budget at time 'X' after spill.

Diesel spills on land and beaches can be handled by two major philosophies. These are:

- Remove, clean and Replace: this approach is said to be generic and involves the physical removal of oil substrate, cleaning them and replacing of the cleaned material back to site. This process involves manual or mechanical means, depending on the onshore environment.
- Reworking and/or Relocation: it entails removing the oiled substrate materials from the upper zone and relocating it to the more active surf zone lower down the beach to take advantage of the natural cleansing and dispersion through wave energy (Dickins, 1990).

A more general means of oil removal on land and on-shore includes the following methods:

- low pressure water flushing of free oil from sediment surface,
- use of high pressure cold or hot water flushing (Hydro blasting)
- Vacuum suctioning of thick oil pools from trenches laced with visqueen
- Pumping of bulk oil from the sediment surface
- Use of absorbent materials to soak up oil from sediments and pavements
- In situ burning of oil on weathered and dry vegetation
- Vegetation cutting, picking and raking, manual removal of oil debris and
- Physical removal by scooping of oil into temporary storage facilities
- Use of steam cleaning under high pressure to dislodge very viscous oils
- Complete excavation of contaminated soils
- Mixing and tilling of soil,
- Surf washing
- Application of sand under high velocity to remove oil by abrasive action (sandblasting) {Breuel (ed), 1981a; API, 1985; Owens, 1999}.

On land or beach area, where manoeuvrability permits, the most reliable combination of equipment is motorised graders and elevating scrapers for the job of removing and relocating sediments (Breuel, 1981a). It is very effective for sandy and gravelled beaches and shorelines where the oil penetration is between 0 – 3cm and having good trafficability. Another excellent tool used is the front-end loaders and bulldozers. These are frequently used to make out appropriate tracks for the clean-up area. Yet another device is the crawl tractor and back hoe used to push the elevating scrapers by increasing traction. The use of vacuum trucks and suction pumps has greatly been documented for sucking up oil into containers. Other equipment for onshore operation may include items like: dragline, dump trucks, steam cleaners, small skimmers, clamshell, trucks, debris box, pumps, hoses, and many others.

Spill occurrence on water due to blow-out from drilling rigs, vessel demise, under water pipeline rupture, or flow into water bodies can be cleaned up by the following methods:

- Use of Booming, skimmers and temporary storage tanks for recovery
- In situ burning of fresh oil on the beach with driftwood or fire booms
- Use of Herding agents (oil solidifiers): for small scale spills on calm waters
- Use of dispersant application: for protecting sensitive shoreline priority
- Use of sinking agents (API. 1985).
- Use of sorbents, most preferably in very calm waters like lakes, and ponds
- High pressure water flushing of oil from shallow area to larger water bodies for collection (Owens, 1999).
- Natural cleansing process-'no action stay'

The choice of equipment used for the clean-up of water bodies or recovery of diesel spill can constitute a difficult choice depending on the objective of the operation and given the quick evaporative nature of such oil. FT-diesel on been contained would usually not form thick pools over long period of time. Its thickness would be in the range of 0.0001 to 0.0003mm in open waters since it forms more of iridescent and sheens (O'Hagan, 2006). If the focus is to reclaim the product, then, the system must be in a prepared state of complete pro-activeness since time is of essence.

These equipment used which range from skimmers, membrane filtration and chemical agents have to be carefully selected for FT-diesel spills. A better understanding of the major device for recovery (skimmers) would guide the right practice for effective clean-up which depend on the fluid properties of specific gravity, surface tension and viscosity.

Skimmers are simple, dependable and effective tool for removing oil from water. It usually utilises the motion of a moving medium to remove the oil. The medium may be belt, disk, drum, baffles, mop-like tendrils which most be oleophilic in nature. The removal of FT-diesel with its low flash point should require skimmers with motors that are explosion proof or air driven in other to avoid fire outbreak or explosion during clean-up. In consideration of the quick evaporation rate of FT-diesel after spilling, skimmers that would be used need to have a very high removal rate to ensure reasonable amount of the product is recovered. Though FT-diesel would have easy flow or suction by skimmers, it would also suck more water into storage which can be decanted in a separation tank. This short coming may make the recovery less efficient because of the extra cost incurred for reprocessing of the oil recovered. A delicate trade-off is required which is dependent on the objective for clean-up (either discard or reuse).

In the oil industry various skimmer types exist. They range from:

- Suction skimmers
- Belt skimmers
- Mop skimmers
- Large tube skimmers
- Mini tube skimmers
- Disk skimmers
- Drum/barrel skimmers (Hobson, 2003).

Suction skimmers are used for removing thick layers of oil and picks up lots of water. Most favoured for open environment clean-up. Belt skimmers are mostly small size industrial application. It has various belt medium ranging from stainless steel, elastomers, standard polymer, and fuzzy polymer fabric. Small spills of FT-diesel in industrial areas are best handled by skimmers with fuzzy polymer fabric for their relative effective recovery over other kinds of belt skimmers. Moreover, belt skimmers with wiper blades made of standard nitrile materials (Buna-N) is considered effective for most liquid clean-up (Hobson, 2003). The drum skimmers are noted for their high removal capacity. Mop skimmers, though effective in light fluid recovery like FT-diesel, has the disadvantage of high water intake and frequent replacement of tendrils and more waste generation. A disk skimmer on the other hand, has relatively low recovery capacities due to smaller area of disk immersion in fluid.

The other factors of consideration when choosing a skimmer would include portability, temperature of environment, water surface stability, size and design, shape, maintenance requirement and operating conditions. The most important factor is the recovery rate and skimmed water content (Hobson, 2003). Additionally, it is important that skimmers with better safety appeal, low maintenance cost and less waste generating ability be used.

Disposal involves processes that ensure that secondary contamination is avoided from recovered oil and oily sludge and waste generated in the course of clean-up. This principle greatly emanates by use of physical techniques in oil removal. Biological and chemical techniques approaches to oil spill recovery produces little or no oily waste in the open environment and is less applied due to its environmental concerns. On the other hand, it is less emphasised due to extra cost that arises due to re-processing and at a smaller scale it may be effectively utilised in the industry for clean-up. Disposal handling from marine environment is less cumbersome than from onshore environment due to the production of only liquid waste instead of gamut of leaves, sludge, substrate, emulsification, tar balls, and oil from shore areas (CONCAWE, 1980).

DISPOSAL METHODS
Oil/water Separation Technique: Density separators, Circular clarifiers & Filter, Oil/water separation, Baffle and weir arrangement, Compact skid mounted units
Emulsion-Breaking Technique: Heat exchanger & Heating coils, demulsifiers
Solid washing Techniques: Cold water, Hot water, Fluidised centrifuging, Steam
Thermal Technique: Pyrolysis, Thermal unit (TU), deballasting system etc
Stabilised Oily waste Technique: Civil works utilisation, Land filling, Farming etc
Destructive Technique: Composting, on-site burning, Incineration etc.

Table 3.2 Oil and Oily debris Disposal Methods (CONCAWE 1980, Breuel, (ed). 1981b).

A look at table 3.2 shows various methods and strategies employed in oily waste and debris disposal. Some of these techniques attempts to recover the oil for re-use while others disintegrate oil debris to more useful materials. For example, the destroyed oil act as a soil enhancer, recycled oil acts as a source of raw material for other use like production of energy and for civil road construction or as a blending stock. Several techniques can be used at same time to achieve a better result at closure of disposal process.

An important point to bear in mind is the continuous monitoring of the air, ground water quality, and ecological diversity of the area where disposal has taken place. This is crucial in other to confidently determine the degree of contamination if any and to make informed decision on remediation where required.

A better objective for spills involving FT- diesel is to reprocess the oil sludge for re-use having considered the economic value of such product and for as long as the gross production cost does not eliminate profit. The use of the word disposal in this dissertation emphasises activities carried out on oily waste and sludge with the intent to have a secondary use for it or assimilated into the environment without harm. The promotion of physical or mechanical means of disposal and oil recovery is expected to continue to the disadvantage of dispersant and chemicals application. GTL diesel is considered 'green' oil having an outstanding property and such use of chemicals would cause more harm to the environment than the oil itself.

At a finer clean-up level in the open environment, remediation techniques may be introduced to remove residual oil and at the industrial zones. Use of absorbent materials or membrane filtration is gaining popularity as an effective solution to total oil recovery and cleaner environment (Baird et al, 2002). Remediation options employed in oil spill clean-up is a natural process involving degradation by bacteria and other micro-organisms known as bio-remediation.

Bio-remediation is usually applied on shoreline sediments or land area contaminated by oil spill and requires aeration of sediments to be most effective. However, there are certain anaerobic degrading micro-organisms existing as well. Bio-remediation has also been demonstrated to be successful in fresh water environment. Bio-remediation is seen as an accelerator of bio-degradation process. The bio-remediation methods include:

- Activation of indigenous micro-organisms
- Seeding of new bacteria (Bio-augmentation)
- In-situ application of N-P-K fertilizer to contaminated environment.

Bio-remediation of environment contaminated by GTL diesel would be seen to be achieved at a faster rate due to the presence of mostly alkanes which are readily bio-degraded. Furthermore, it will dissipate more easily on shorelines or absorbed into sediment due to its property and would ensure quicker recovery for the environments especially were groundwater supply in threatened. But where arable land is exposed to FT-diesel spill, the use of fertilizer is most encouraged. Fertilizer application has been seen and documented to work in several places around the world (EPA 1990, NOAA 1992, Swannell et al 1996.) and should constitute one of the BMP at rehabilitating affected Lands.

A proactive approach would be for oil and GTL diesel related industry to have in stock fertilizers like Inipol™ and Custoblen™ as part of the contingency plan document inputs. Moreover, farmlands around such facility stands to gain from the enrichment the soil gets on been treated from fertilizers during remediation. The use of such farmlands should be treated with caution – allowed to fallow for at least a year and preferably economic trees suffice planting unless were laboratory analysis of the remediated and enhanced soil proves otherwise.

A combination of techniques has also been shown to work effectively (Swannell et al, 1996). Like the addition of fertilizer application and indigenous organism activation. In some other cases, a combination of fertilizers and augmentation is preferred.

It has also been observed that microbes with the capacity to degrade oil are present on water surface in all inland and coastal environment and such surroundings are further influenced by other factors such as temperature, water-runoff, and substrate. Baird et al (2002) also believes that the type and concentration of microbes of choice, bio-catalyst, and nutrients is a strong determinant in establishing effective bio-remediation. Nonetheless, for bio-remediation to occur, the hydrocarbon degrading microbial population must achieve a density of one million microbes per gram.

Soil and water bodies around GTL diesel plant should be subjected to microbial analysis to determine indigenous micros and its distribution. This will help to decide appropriate remediation strategies were needed. Such preparedness should also be addressed in the SCP document. Additionally, a rehabilitative strategy should be to set-up a nursery to grow mangroves and sensitive vegetations as a transplant programme initiative in preparation for eventuality.

It has become important to evaluate the level of clean-up and remediation carried out within a contaminated environment. This process can be simply described as "Enhancement". On land and shoreline area following clean-up and remediation, certain monitoring and testing action need to be done such as:

- ❖ Screening with vapour detection device such as an H-nu, OVA, or other photo-ionisation device to look for "hot spot" where heavy odour still persist.
- ❖ Excavation and disposal of affected soil should be followed by soil testing of the area periodically to show whether adequate remediation has taken place and when to stop further actions.
- ❖ Ground water monitoring should be initiated periodically, especially where the water table is very shallow.

Substrate are to be tested for Total Petroleum Hydrocarbon (TPH) in accordance to method 8015 modified diesel range organics (DRO) and possibly BTEX method 8021B for benzene (ODEQ. 2006). This testing and monitoring would aid to confirm efficient clean-up. It is best that sampling be done according to standard practice, especially from places of greatest impact (visual concentration).

This 'enhancement' practice is predictive and can be used to forecast when an environment becomes clean. Enhancement practice is a decision tool to either continue 'response' or closeout clean-up process. It also tells us the degree of remediation attained. The acquisition of these monitoring and measuring devices is highly recommended for inclusion into the contingency plan document and procurement of same for use will be the ideal thing.

Groundwater has always been a source of concern and for this reason certain compositional benchmark has been recommended by different institutions which vary from country to country. According to the ODEQ, (2006) the emergency spills of diesel or gasoline into the environment should accommodate a conservative clean-up value to protect groundwater (Table 3.3 below).

ACCEPTABLE HYDROCARBON COMPOSITION IN GROUNDWATER		
TPH	50.00 mg/kg (ppm)	
Benzene	00.04 mg/kg (ppm)	
Toluene	20.00 mg/kg (ppm)	
Ethylbenzene	15.00 mg/kg (ppm)	
Total Xylene	167.00 mg/kg (ppm)	
TCLP test	<400 mg/kg (ppm)	Hazardous waste assessment

Table 3.3: Minimum HC Concentration in Groundwater. (Oklahoma-DEQ, 2006),

If the monitoring and evaluation process carried out on soils show values below the set standard (as shown in Table 3.3), then no further action would be typically required and vice versa. Substrate which meets set standards can also be used as back fill material for excavated area.

3.5 SPILL, PREVENTION, CONTROL, COUNTER-MEASURE PLAN [BMP]

The history of events involving oil spill response process has engineered a shift of paradigm in the industry towards continuous improvement in the areas of risk reduction and prevention by extended planning process. This level of planning which attempts to forestall operational efficiency in handling of oil, oil by-products, and 'spill response process' is known as Spill Prevention, Control and Counter-measure Plan (SPPC Plan). According to the United States code of federal register (67 FR 47140, July 17, 2002, as amended at 71 FR 77292, Dec. 26, 2006) a, SPCC Plans are designed to complement existing laws, regulations, rules, standards, policies, and procedures pertaining to safety standards, fire prevention, and pollution prevention rules.

The content of this document has been adopted greatly in the United States and United Kingdom with other western countries following suit. It requires a level of legal framework to ensure it's applicability in the industry worldwide and it is expected to become a benchmark for effectively measuring best management practice in the industry. It's core objective is to completely prevent spillage or adequately control unwanted effects to ALARP by putting certain physical structures in place right from the design stage of facilities to its operation-support stage and finally to its disposal phase.

Planning which has been defined as a process of developing and formulating a course of action to be taken in the future (Blanchad et al, 1980), is also a systematic identification of programme task, schedules and resources required for task accomplishment. SPCC plan is very important to ensure little or no disruption in process activities that may cause spill. SPCC planning is based on experience obtained over the years and measure of forecast. SPCC plans are seen as additional plans to an already existing contingency plans of facilities. Research has also shown that planning influences the success of a project by 60% (Steyn et al, 2003). Based on this practice, it has been suggested that facilities should have an Integrated Contingency Plan document (ICP) comprising the facility spill contingency plan, emergency response plan, pollution prevention and preparedness plan and the spill prevention, control, counter-measure plan all in one document (Decker, 2003). Decker, (2003) believes it is a better cost effective approach for upcoming oil process facilities. Although it is time consuming.

SPCC plan document scope, profiles certain oil industry asset base. They include pipelines, sea going vessels, storage tanks, process plants and retail stations. The purpose of the plan is to achieve the following:

- Identification of sources
- Identification of oil storage containers and equipment
- Identification of spill prevention procedures
- Identification of spills pathway
- Identification of good housekeeping practice aimed at reducing risk by
    - Implementing storage Tank Management Programme (STMP)
    - Conducting safety and operational training on annual basis
    - Carrying –out periodic inspection and regular audit.
- Identification of deviations from regulatory requirements ascertaining compliance.

SPCC Plan must be developed and implemented for facilities that store more than 1,320 gallons of oil above ground in containers and oil filled equipment equal to or greater than 55 gallons in size of any oil type in order to assess the potential for spills and releases. (US-CFR Title 40 Part 112, 67 FR 47140, July 17, 2002, as amended at 71 FR 77292, Dec. 26, 2006) a.

The emphasis is on erecting or using permanent structures for controlling and preventing spills. Some of these preventive approaches include the following:

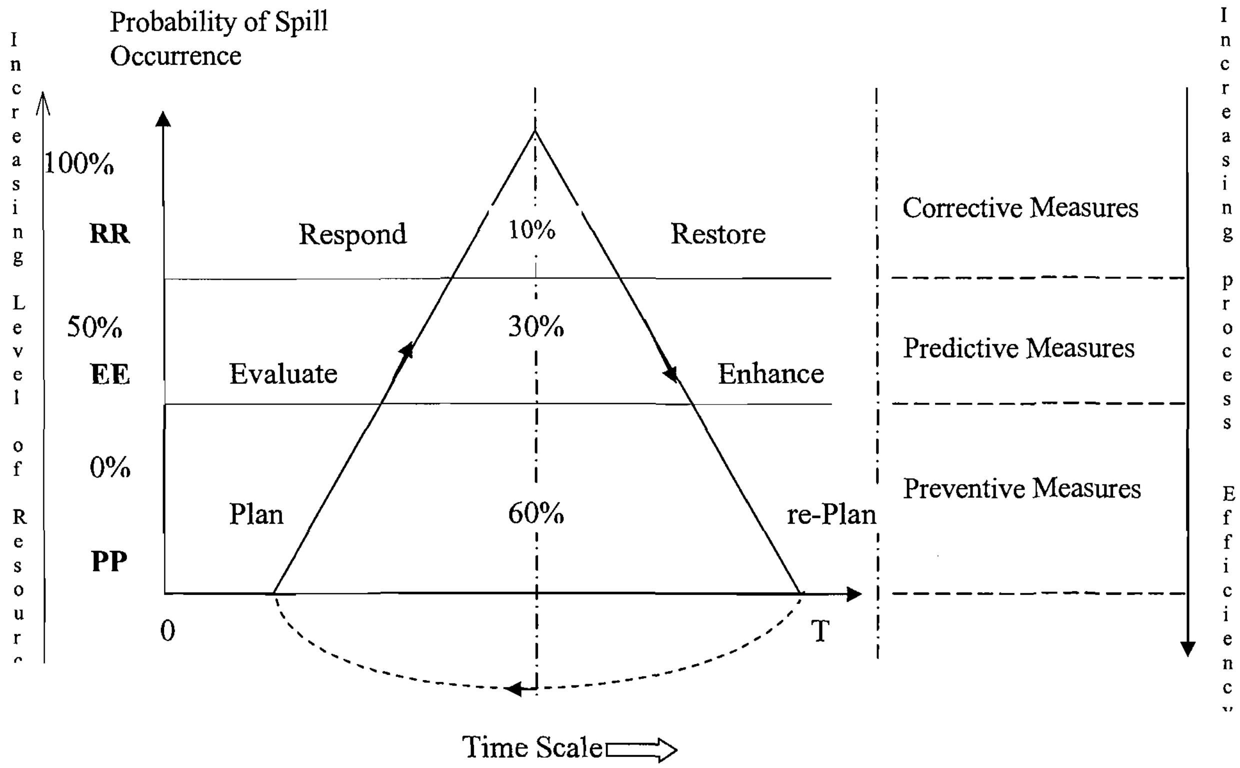
- The building of a 'loading platform' for a GTL plant like in Excravos, Nigeria should involve the construction of the loading arms to be hydraulically controlled with a dry disconnect couplings to eliminate spillage.
- A second focus will be to assemble future oil pipeline network deep underground and beneath the subsurface under the sea, this will help eliminate frequent spillage due to vandalisation and human operation error.
- The installation of a ballast water treatment facility (BWTF) within the terminal area where GTL plant exist would serve to treat storm water runoffs, industrial water and ballast water from loading and off-loading tankers. This will help to reduce diesel spill discharge into the river/sea and around the harbour (ICRC &SC, 2002).
- Another measure would be to surround all oil tankers at a loading or docking bay with a containment boom during anchor and transfer operations (Breuel, 1981a).
- It is now recommended that all oil tankers must have double hull design technology to reinforce stability of vessel during operations and prevent sudden rupture.
- All storage facility must be surrounded with a bund wall or concrete dikes of the 110% of the largest tank volume as a protective envelope in the advent of a tank rupture or collapse.
- All process areas involved in the diesel production should be constructed such that they are all partially enclosed by side walls to form a kind of containment in the advent of sudden spill.
- The plant construction should also be built with 'storm water pollution prevention plan' for constructional activities. This will act as control tool for erosion prevention, proper draining and collection of spilt oil (ICRC &SC, 2002).
- Equipments for response to vessels on sea should be light weigh such as submersible pumps of a construction which allows use through the butterfly openings in tankers deck and use of lightweight collapsible plastic hose for ship to ship discharge.
- A Floats switch, timer, variable speed drive, power packs, warning light and control panel should be installed to monitor fluid level in all oil collection drum which helps prevent overflow (Hobson, 2003).

- Provide appropriate containment and/or diversionary structures or equipment to prevent a discharge. At a minimum, see appendix B for containment prevention systems or its equivalent.
- Inspections, tests, and records: Conduct inspections and tests required by this part in accordance with written procedures that you or the certifying engineer developed for the facility.
- Personnel, training, and discharge prevention procedures. At a minimum, train your oil handling personnel in the operation and maintenance of equipment to prevent discharges (US-CFR Title 40 Part 112, 2006).

The reader is here referred to Appendix B for a detailed provision of the prevention acts of the US congress which guides the provisional elements of the SPCC Plan.

4.0 <u>CHAPTER FOUR</u> (MODELLING /SIMULATIONS/TRADE-OFFS)

4.1 CONCEPTUAL MODEL OF OIL SPILL RESPONSE LIFE CYCLE



Conceptual Model of Spill Response process Life Cycle

Figure 4.1 PERREP Model for Oil Spill Response Life Cycle.

In the researchers' opinion, the activities of an effective system for executing oil spill response action are as shown in figure 4.1. This is a systematic flow of events technically speaking. There are other side activities which may not affect the cycle. The researcher wishes to call this model the PERREP model for oil spill response process life cycle. This is actually a concept of my thought process; it is subjective and as such should be applied and accepted with caution.

PERREP stands for Plan, Evaluate, Respond, Restore, Enhance, and re-Plan. It showcases the various steps oil spill response should undergo to effectively achieve mitigation ALARP. The model is spread in three phases: PP phase, EE phase, and RR phase (figure 4.1).

PP phase involves rigorous planning and depicts a high level of preparedness in the case of eventuality. In the oil spill response process, PP phase entails the aspects of Spill contingency planning, Standard Operating Procedures formulation, responder training and Spill prevention, Control and Counter-measure planning. This phase is descriptively a preventive measure that is employed in spill response. The researcher believes that the spill response process should dwell more on planning which should not be less than 60% in time value and of resources made available in the life span. This can only ensure better implementation result and little or no need for a 'Respond' action.

The beginning of most new facility around the world attracts this level (PP phase) before the plants starts to process oil products that might pollute the environment. As such the chance of spill occurring at this stage in the life cycle is non existent (0%). PP phase should be more characterised by integration of People (ρ), Knowledge management (Ψ), and Technology (τ) as essential ingredient for optimisation of oil spill response thinking. Adequate implementation of the BMP of 'Planning' elements from the onset would ensure an improved management approach to oil spill response process.

EE phase is essentially an analytical period in spill response which spans to confirm spillage or absence of same. EE phase involves evaluation and enhancement actions carried out before, during and after a spill have occurred. It creates room for detection to be made on what is and likely to happen in the future with oil spills. It generally involves surveillance tracking, monitoring, inspections, mock emergency, testing and carrying out estimation on the state of the environment. This phase is descriptively a predictive measure in oil spill response.

It is my candid opinion that response actions should concentrate 30% or more of time and of resources value to this phase in the response process. This can only ensure considerable risk reduction, clean-up cost savings, and reliability of the response process in implementing RR phase. Together with the PP phase actions, they constitute a proactive approach in carrying out oil spill response. The likelihood that spill has occurred and might occur at this EE phase is 50% during the response life cycle. Although an effective and well implemented PP and EE phase actions can completely eliminate spills.

The EE phase is characterised by Technology (τ), People (ρ) and Knowledge management (Ψ) as seasoning for efficiency during spill response. It will require greater utilisation of computer aided simulations to be ahead of events which will foster successful combat operation. The EE phase actions in response process to FT-diesel spills will make the distinction as an improved management approach to spill combat by use of long-time and real-time simulations to forecast and make timely decisions.

RR phase is the climax of an oil spill response process. It is this stage that makes all the difference as to whether an environment returns to status quo. It is actually the implementation stage of a clean-up action. RR phase involves containment, recovery and disposal of spilt liquid known as 'Respond' action and the 'Restore' action which attempt to remediate and; or rehabilitate the environment. Once an oil spill is established this phase swings to action. RR phase is basically a corrective measure of mitigating effects.

The RR phase can be done very efficiently and in a timely manner known as 'rapid response' depending on the quality of inputs from the EE phase. The activation of this phase is an assurance that spill has occurred (100%). It is a known fact (from literature reviews) that spill is inevitable, only a matter of time for it to happen. This fact would allow a focus of 10% or less of time and resources value in the spill response life cycle be allowed to RR phase or completely eliminated were possible. Moreover, the need to be combat-ready by a good PP and EE phase implementation cannot be overemphasised, since this will help to reduce time and resources spent on clean-up.

The RR phase can go on for weeks to years to be conclusive. It also requires higher level of resources to implement as a result of administrative, material, operational and logistic concerns. This phase is usually characterised by people (ρ), process (ℓ), technology (τ) and knowledge management (Ψ). Experience has shown the RR phase to be most reverberating due to poor handling of PP and EE phase by organisations and entrepreneurs. This situation has created a wrong perception in the society and a myopic focus of responders to what oil spill response service is all about.

The flow of event from PP, EE to RR shows an increasing level of resources required from a project management perspective. This trend should be avoided as much as possible by stakeholders (Oil spill response contractors and facility operators) by keeping the response process within the first two levels and by rendering services that promotes prevention and analysis. This by so doing will encourage increased process efficiency from RR, EE to PP phases. The ability of the industry operatives to recognise the stage they are in, in the process life cycle would aid in strategising there oil spill response system for optimisation and sustained relevance.

The implementation of PERREP is a closed loop scenario with one activity re-informing the other as time progresses. As the service life cycle progresses, lessons learnt should be well documented and act as inputs for the succeeding stages. This ensures continuous improvement in the process. The PP phase should be constantly reviewed, the EE phase should be continuous as well as periodic depending on the objective of the action; and the RR phase should be avoided or kept at minimal.

4.2 SIMULATED CHARACTER ANALYSIS OF SPILL FOR GTL-DIESEL

4.2.1 BRIEF BACKGROUND

The zone in consideration is the Excravos River area in Niger Delta province in South-South Nigeria. The Excravos River area lies along the coastline belt (latitude 4 10' to 6 20'N and longitude 2 45' to 8 35'E) of Nigeria which stretches for approximately 853km facing the Atlantic Ocean (Nwilo and Badejo, 2001). The Excravos mouth area itself lies within 5 30'N and 5 5'E. This area is usually influenced by monsoon currents orienting SW and the warm guinea current oriented E. the coastlines around the Excravos area is known for its Sand, Silt and mud deposits at beaches and is characterised by delta fronts and numerous streams. The vegetation is known to range from mangrove swamp, fresh water swamp, lagoon marshes, tidal channels, beach ridges and sand bars. The coast line is generally forested by their unique vegetation.

This land accommodates the ChevronTexaco oil Terminal operations. It is also the location for the instituted GTL plant that will produce mainly FT-diesel under the auspices of SasolChevron Joint Venture. The Excravos area lies on the coast and the

Excravos River is adjacent to the harbour on which all operation vessels ducks and empties into the Atlantic Ocean.

It is important that we think one step ahead, by predetermining what might happen to FT-diesel spill around such an environment with its unique weather properties. It is also on record that the coastal waters around Excravos has once suffered spillage of over 300,000 barrel in 1978 (Nwilo and Badejo, 2001). This re-enforces the need to curb a future threat of expanded oil production in the area.

4.2.2 PURPOSE OF SIMULATION

- The primary purpose is to show computer aided simulation as one of the steps towards improved management approach to oil spill response.
- The secondary aim, attempts to establish the fate of FT-diesel when spilt into the coastal water of the Excravos area.
- To determine the oil trajectory after spillage
- To determine areas and priorities that needs to be protected
- Finally, it will assist responders in decision making for adequate and reliable contingency planning elements by prediction and forecasting what might happen to FT-diesel in such environment.

4.2.3 MODEL DESCRIPTION

The ADIOS 2.1 Software (Appendix C) and GNOME for modelling spill scenarios was downloaded from NOAA website and used for this simulation. This was further studied and all input parameters noted. A custom oil database file was created by the inputs from the characteristics of FT-diesel from earlier chapter (Table 2.2) as compiled from literatures. The simulation was done to determine the oil budget, weathering rate and process of FT-diesel in such natural environment. ADIOS2 (Automated Data Inquiry for Oil Spills) is a physical fate model that determines distribution of oil mass and concentration on water surface, shoreline, in water column, and in sediment (NOAA, 2006a). ADIOS is designed with a weathering algorithm incorporating lagrangian discrete particle tracking of the natural physical processes and water transport dynamics in the oil fate analysis.

Four scenarios were considered, oil spill involving minor discharge of 1000 gallons, a medium discharge involving 10,000 gallons and a major discharge involving 100,000 gallons and a "Worst-case" discharge within the coastal water of the Excravos river area for open system. The simulation is a time trend based event, as such the scenarios were also conducted to cover 1hours to 5 days. Further data was sourced from what is relatively known of the Excravos river area from online literatures and should be considered generic in nature such as the average wind forecast. This led to proximal values being used as inputs.

The sensitivity analysis of the four scenarios kept the wind value and direction constant and only varied the amount of oil spilt over time. The "worst-case" scenario was run by use of the highest obtainable input variables such as water temperature, water current speed, wind value and direction, wave height, and 1,000,000 gallons of spilt GTL diesel. This combination of input variables would reflect the greatest potential hazard in and around Excravos River.

All input variables were entered into the data windows that are displayed for oil properties, weather conditions, water properties, and oil release scenarios. This is then followed by clicking 'Solve' to generate the oil weathering sequence over time. The processes simulated include density, viscosity, evaporation, oil budget, remains, dispersion and water content. These parameters of the oil are automatically graphed and plotted against time. The software also produces the 'Release Report' and oil budget table from which other inference can be made about the spill. These processes were repeated severally with each scenario to generate outputs.

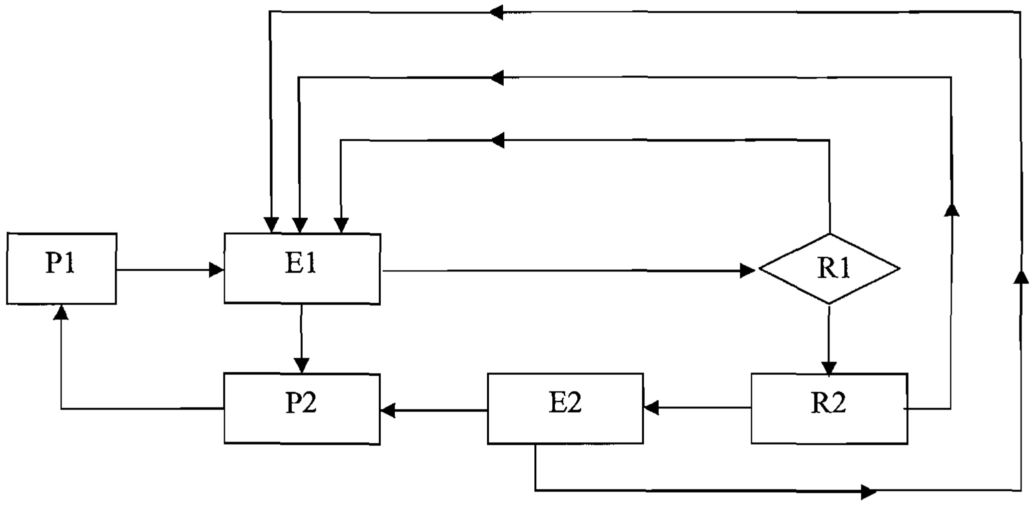
The use of Computer aided analysis is an evaluation tool which re-enforces adequate planning (P1 and P2) as is modelled in figure 4.2 (below). This allows for timely prediction to be made and is pivoted on continuous feedback to E1. This assures that the response process goes on efficiently. The simulation is one of the evaluation (E1) tasks that should always be carried out and acts to validate the inclusion of this activity among the oil spill process elements (PERREP).

4.2.4 DATA COLLECTION: INPUT VARIABLES

▪ FT-diesel properties	see Table 2.2
▪ Wind Speed considered	8mph 15mph,
▪ Wave height considered	1m, 2m
▪ Water temperature considered	20°C 33°C,
▪ Water Current	0.6knots – 2.5knots
▪ Water Salinity	10‰15‰,
▪ Dissolved salt	120mg/ℓ
▪ Sediment Load	$21800m^3$/annum
▪ Open water thickness of FT-diesel	0.0003mm, 0.0001mm
▪ Estimate of Horizontal mixing	20m 40m,

The minimum values of all the variables were used for running the scenario for the minor, medium and major spill. Maximum variable were used for the worst-case scenario, except the water salinity and sediment load values that were averaged as inputs into the software programme.

The followings sites: www.fao.org/SWIwppr/reports/Y sf/z ng/ng.htm, http://www.weather.com/outlook/travel/businesstraveler/wxdetail/wixx0017?dayNum=1, http://polar.ncep.noaa.gov/waves/latest run/nww3 at.hooh.gif, http://www.marineplaner.com/bowditch/chapt.32.pdf was consulted for above stated input values and others were obtained from the body of literature above.



LEGEND

P1	Plan (Spill Contingency Planning)
E1	Evaluation (surveillance/inspection/prediction/testing)
R1	Respond (contain/recover/dispose)
R2	Restore (remediation/rehabilitation)
E2	Enhancement (monitoring/testing/audits/estimation)
P2	Plan (Spill Prevention, Control, & Counter-measure Planning)

Activity Flow Diagram of PERREP Model for Oil Spill Response.

Figure 4.2 Block diagrams showing relative position of Oil Spill Response activities.

4.2.5 DATA ANALYSIS: OUTPUT VARIABLES

All the data output is Time-weighed. The focused parameters are graphed in 'Percentage' versus 'Time' for ease of interpretation and comparison. The runs were done in static wind mode. No response strategy is considered in the simulation in order to exactly show how nature handles the clean-up of FT-diesel. Interpretation focus was restricted from the first to the twenty-fourth hour after spillage.

Spill Scenario - Oil Budget Table

ADIOS® 2.0 .

```
Oil Name = FT-DIESEL (GENERIC) (custom oil)
API = 48.3   Pour Point = -18 deg C
Wind Speed = constant at 8 mph Wave Height = 1 meters
Water temperature = 20 deg C
Time of Initial Release = June 01, 1200 hours
Total amount of Oil Released = 1000 gal
---------------------------------------------------------------
```

Hours Into Spill	Released gal		Evaporated percent		Dispersed percent		Remaining percent
2	1,000	-	27	-	22	-	51
3	1,000		34		33		33
4	1,000	-	38	-	40	-	22
5	1,000		39		45		16
6	1,000	-	40	-	49	-	12

Table 4.1a Excravos River FT-diesel Spill-Oil Budget_1,000 gallons_Scenerio1

Spill Scenario - Oil Budget Table

ADIOS® 2.0 .

```
Oil Name = FT-DIESEL (GENERIC) (custom oil)
API = 48.3   Pour Point = -18 deg C
Wind Speed = constant at 8 mph Wave Height = 1 meters
Water temperature = 20 deg C
Time of Initial Release = June 01, 1200 hours
Total amount of Oil Released = 10000 gal
---------------------------------------------------------------
```

Hours Into Spill	Released gal		Evaporated percent		Dispersed percent		Remaining percent
2	10,000	-	9	-	5	-	86
3	10,000		16		12		72
4	10,000	-	24	-	21	-	56
5	10,000		30		30		41
6	10,000	-	34	-	38	-	29
7	10,000		36		43		20
8	10,000	-	38	-	48	-	15
9	10,000		38		51		11

Table 4.1b Excravos River FT-diesel Spill-Oil Budget_10,000 gallons_Scenerio2

Spill Scenario - Oil Budget Table ADIOS® 2.0 .

```
Oil Name = FT-DIESEL (GENERIC) (custom oil)
API = 48.3    Pour Point = -18 deg C
Wind Speed = constant at 8 mph Wave Height = 1 meters
Water temperature = 20 deg C
Time of Initial Release = June 01, 1200 hours
Total amount of Oil Released = 100000 gal
```

Hours Into Spill	Released gal		Evaporated percent		Dispersed percent		Remaining percent
1	100,000	-	0	-	0	-	99
2	100,000		2		1		98
4	100,000	-	6	-	4	-	90
6	100,000		13		10		76
8	100,000	-	20	-	20	-	60
10	100,000		26		30		44
12	100,000	-	31	-	38	-	31

Table 4.1c Excravos River FT-diesel Spill-Oil Budget_100,000 gallons_Scenerio3

Spill Scenario - Oil Budget Table ADIOS® 2.0 .

```
Oil Name = FT-DIESEL (GENERIC) (custom oil)
API = 48.3    Pour Point = -18 deg C
Wind Speed = constant at 15 mph Wave Height = 2 meters
Water temperature = 33 deg C
Time of Initial Release = June 01, 1200 hours
Total amount of Oil Released = 1000000 gal
```

Hours Into Spill	Released gal		Evaporated percent		Dispersed percent		Remaining percent
1	1,000,000	-	1	-	0	-	99
2	1,000,000		2		1		96
4	1,000,000	-	8	-	6	-	86
6	1,000,000		15		16		69
8	1,000,000	-	22	-	27	-	51
10	1,000,000		26		37		36
12	1,000,000	-	29	-	44	-	27

Table 4.1d Excravos River FT-diesel Spill-Oil Budget_1,000,000 gallons_Scenerio4 (WCS)

4.2.6 SIMULATED RESULT: INTERPRETATION AND VALIDATION

Scenerio_1:1000 gallons spill at minimum input values shows that the FT-diesel would have been lost with about 12% of it left for recovery after 6 hours and definitely none is likely to be recovered after one day (Appendix D1-D). The sixth hour after spill is the breaking point within the window of opportunity for meaningful recovery. Beyond the sixth hour the best that can be done would be to remediate the environment if desired.

FT-diesel undergoes two major processes (Appendix D1-A): dispersion and evaporation. Dispersion has a greater influence than evaporation after the third hour as seen on the oil budget table (Table 4.1a; Appendix E1), combined they make up 89% loss of FT-diesel under 6 hours of been spilt and complete vanish within 18hours (Table4.1a).

Scenerio_2: 10,000 gallons spill at minimum input values shows that the FT-diesel would have been lost completely in 21 hours. 11% will be left to be recovered after 9 hours (Appendix D2-D). The 9th hour after spill is the breaking point for this amount of spill involving FT-diesel in Excravos River. The window of economical recovery would lie within 9 hours after spill.

The sixth hour after spill shows that 72% of the product would have been evaporated and dispersed into the environment. Evaporation and dispersion are very evident in this simulation (Appendix D2-A). Dispersion also has a greater influence than evaporation by margin of not less than 4% of spill volume from the sixth hour after spill and increases onward after then much more than evaporation (Table 4.1b; Appendix E2).

Scenerio_3: 100,000 gallons spill at minimum input values shows that the FT-diesel would be lost in 30 hours and most likely left with 30% of the product after 12 hours (Appendix D3-D). The eight hour after spill is the break point for meaningful recovery of the GTL-diesel. Response after the eighteen hour of spill should attract remediation tasks.

Two major processes are still evident in this volume scenario: dispersion and evaporation. Evaporation takes the lead until the eight hour (Table 4.1c; Appendix E3) after spill by which time dispersion process becomes more dominant with over 4% in volume of diesel spilt. Combined, the process of evaporation and dispersion is responsible for roughly 70% of GTL-diesel lost to the environment after 12 hours of spill.

Scenerio_4: This involved the worst-case scenario of 1,000,000 gallons of GTL diesel around Excravos River. WCS spill would also be seen to be all lost within 27 hours with only 27% left after 12 hours into spill (Appendix 4D_D). The 6th hour after the spill is the breakpoint: window of economic recovery. Evaporation and dispersion are highly evident as weathering processes of influence. The 8th hour after spill sees dispersion being more influential than evaporation with over 5% in volume of spilt oil (Table 4.1d). This also continues to increase as time goes on (Appendix E4). The two processes summed up causes 73% loss in the GTL diesel volume after 12 hours of spillage.

Hours after Spill	**Scenario 1 1,000 gallons**	**Scenario 2 10,000 gallons**	**Scenario 3 100,000 gallons**	**Scenario 4 (WCS) 1,000,000 gallons**
2	49%	14%	3%	3%
3	67%	28%	**	**
4	78%	45%	10%	14%
5	84%	60%	**	**
6	89%	72%	23%	31%
7	**	79%	**	**
8	**	86%	40%	49%
9	**	89%	**	**
10	**	**	56%	63%
12	**	**	69%	73%

** Not generated by simulation.

Table 4.2: Comparative percentage loss of GTL-Diesel in different scenarios over time.

A critical look (Table 4.2) at scenario 1 and 2 would show a greater level of loss comparative to scenario 3 at the 2nd, 4th and 6th hour after spill. This could be attributed to less spreading rate of higher volume diesel on water surface as a result of greater coefficient of adhesion between diesel molecules and less surface area for the impact of sunrays. In other words, large volume of spill (>100,000 gallons) would give a better recovery volume over time than lesser volumes when spilt. In the same way the longer the diesel stays on water before recovery, the less the volume left for collection.

Scenario 4 may not be seen to reflect this trend because it belongs to a different input variable regime with higher values as inputs. However, if it were to be plotted on hind-cast estimate, it would show the same behaviour like scenario 1, 2 and 3. The table (4.2) shows that for spills involving large volume of 100,000 gallons and above, the best time of recovery will be within the first hour after spill in which only 3% of product is seen to be lost and not beyond the 8th hour. Whereas for spills less than this volume, the first hour is critical for recovery of at most 49% of the product and beyond the 6th hour, will leave less to be desired.

A plot of the combined 'GTL Diesel loss' against 'Time of spill' from 'Table 4.2 gives unique curves below (figure 4.3). This graphics shows that scenario 1 and 2 curves are curvilinear and scenario 3 and 4 are relatively straight line curves which allows for linear regression equation model to be deduced by LSBF technique as shown (appendix F).

The mathematical modelled equation for GTL diesel on Excravos River after spill can be used for effective response action. The curves which when populated with further scenarios based on hindcast information for various spill sizes can be used as a 'Quick look estimation Chart' by responders prior to and during clean up operation.

The modelled equation for each curve acts as a prediction tool. For example, the regression model for scenario -3 which is **Y = -14.999 + 6.929 X** has an 'intercept' of **-14.999** and a 'slope' of **6.929**. The slope tells us about the rate of GTL diesel loss to the environment. From this, we can then estimate the amount lost at any time (t) either by tracing it on the Quick-Look-Chart or by inserting the time (t) of interest into the modelled equation.

Furthermore, a look at the curves on the chart (figure 4.3) by imaginary extrapolation would show their origin going to the negative X and negative Y axis. This on its own mathematically speaking, may imply certain degree of microscopic GTL diesel loss prior to spillage and after spillage which is not accounted for by the ADIOS software. This thinking is tenable when one considers natural evaporation that takes place at storage when opened to the atmosphere and the effect of other factors other than dispersion and evaporation that may influence the mass balance however negligible.

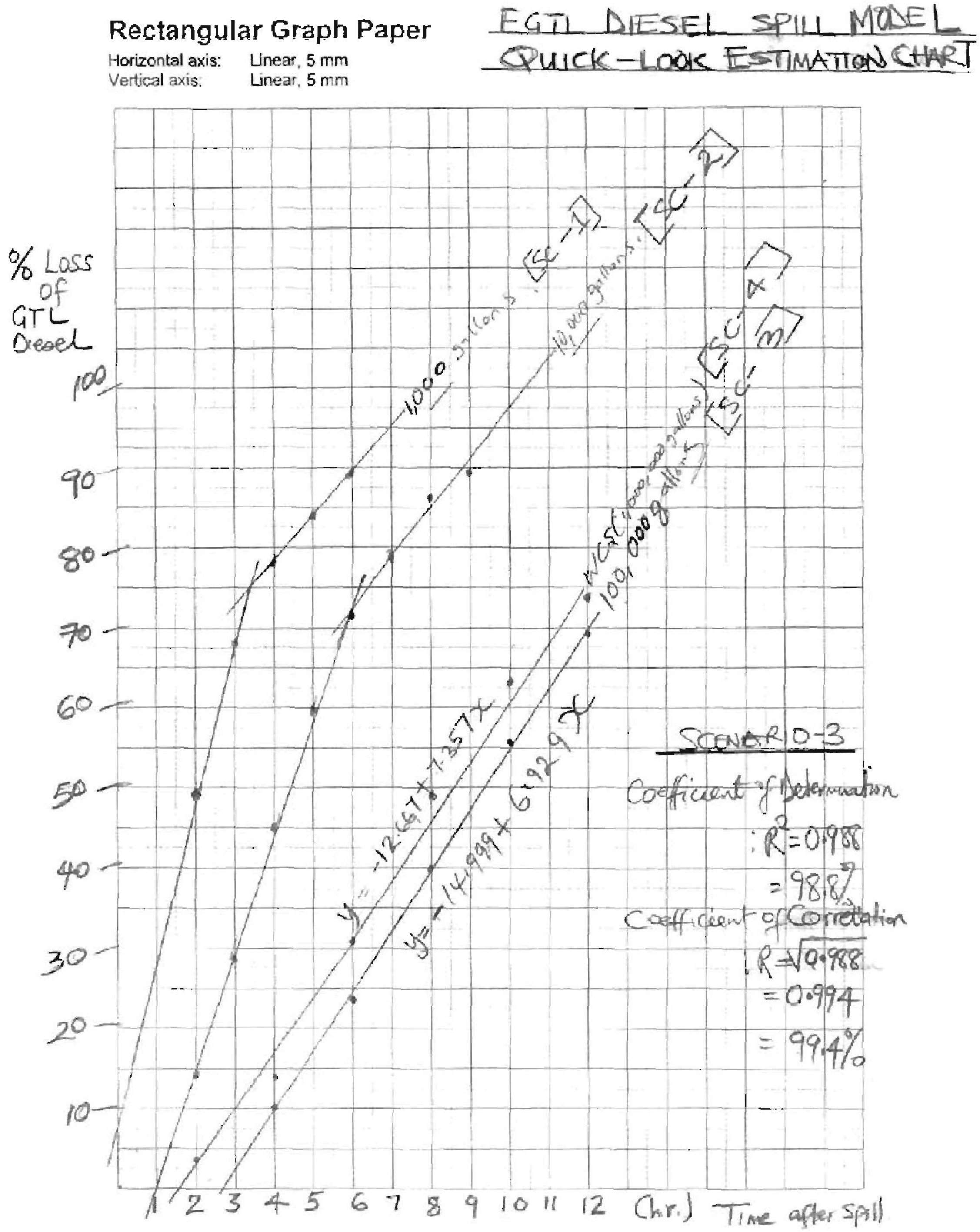


Figure 4.3: **Derived GTL Diesel Spill Quick-Look Estimation Chart**

It can be seen also that the slope has a positive value showing that the quantity of GTL diesel lost is directly proportional to time after spill. In other words, the more time spent after spill, the more GTL diesel is lost to the environment. This is established by the value of 'Coefficient of Correlation (R)' between the variables as 99.4% (figure 4.3;

appendix F). This means that the loss due to the weathering process has a 99.4% extent of direct relationship with Time after spill. The 'Coefficient of Determination (R^2)' on the other hand, has shown goodness fit of 98.9% of the model. This implies that most loss due to evaporation and dispersion of GTL diesel in Excravos River is 98.9% explained and accommodated by the regression equation model. In other words, the ADIOS software is credible in predicting loss due to evaporation and dispersion.

Similar models that have attempted to simulate the weathering characteristic of FT-diesel in open waters are relatively non existent. Such that this work is the first of its kind and a possible precursor for greater and detailed work in the future. This situation makes it very difficult to validate with other run simulation scenarios or with observed field data. The only possible means of comparison would then have to be with existing information on conventional diesels as found in the open literatures and probable feed back from professionals.

The work of Fingas et al (1996) opines that **"fuels such as gasoline and diesel are mostly influenced by evaporation in the environment"**. Thought, this research via modelling has shown otherwise for GTL diesel, to be influenced mostly by dispersion (Table 4.1a – d; Appendix E1-4). Fingas and others also documented that **"diesel fuel will evaporate to the extent of about 60% in about 3 days on warm waters"**. Findings from the modelling, has shown that GTL diesel will evaporate between 30 – 40% (Table 4.1a-d) in half a day. This should be in line/exceed Fingas et al (1996) data were extrapolation is considered. However, a look at the charts (Appendix D: D1-B, D2-B, D3-B, and D4-B), shows evaporation loss of 36 - 40% in 24 hours for GTL diesels as compared to loss of 20 – 30% for most oils in same 24 hours as documented in CONCAWE (1983a:25) and NOAA (1992:C2-3). It is also important to note that Fingas and others considered a combined generalisation for gasoline and diesel behaviour which influenced there judgement. Conversely, the researcher considered only one unique product. Moreover, the lighter weight of GTL diesel and pour point over conventional diesels marks the difference in rate of weathering and quantity lost with time.

The modelling outcome above suggests that GTL diesels evaporates very rapidly within a short life span, this is in line with the work of French McCay et al, (2004).; were diesel and gasoline were reported to **"evaporate off the shoreline rapidly"**. They also found out that rapid evaporation occurs just after the spill which is inline with the result of the scenarios with ADIOS where evaporation is greatest at the beginning and later declines making dispersion most influential at the later period of the spill and overall.

The processes of 'entrainment' and 'dissolution' was documented in the work of French McCay et al, (2004:20) for gasoline and diesel, it was however not directly evident in the run scenario of ADIOS-Excravos simulation for GTL diesels. This outcome may probably be due to some limitations of the software algorithms; non standardization of weathering processes nomenclature or non applicability of this spill processes to the Excravos River area. The use of the word 'entrainment' by French McCay et al (2004:20) may simply stand for 'dispersion' (Cerkirge and Palmer, 2001:9) and if indeed so, GTL diesel spilt around Excravos river would conform to the findings of French McCay et al, (2004).

Earlier study by McLarens (1985:195) from field observations shows also that conventional diesel is easily retained in sediments and is most likely to affect the water table of fresh water supply. The capacity to simulate for diesel spills on land from ADIOS was not considered in this research and should be treated in future study.

Furthermore, NOAA's November, (2006b) publications also confirms the outcome of this model for GTL diesels to be behaviourally compatible to conventional diesels by showing that up to 90% (Table 4.2) of spilt diesel evaporates and get naturally dispersed in a short period. However, its claim is restricted to either of the processes: evaporation or natural dispersion is responsible for such huge loss in a short time. While Excravos-GTL diesel model shows loss arising from both processes. It has also become obvious to the researcher that a thin line exist between 'entrainment, dissolution, spreading and dispersion' such that their clear distinction should be further investigated especially as it affects GTL diesel spills.

Several interactions through electronic mail to Beegle-Krause, Ph.D. (2007) of NOAA office in the United States of America who is a practicing professional in "Spill Modelling" gives a nod on the outcome of the preliminary simulation results for EGTL diesel scenarios (Appendix H). He believes EGTL diesel conforms to a large extent to behaviours of conventional diesels though unique.

4.2.7 LIMITATIONS and CONSTRAINTS

There were challenges faced by the researcher while carrying out this modelling. They are:

- ❖ Incomplete parameter values for GTL diesel properties due to enterprise policy on classified information for relatively new findings.
- ❖ ADIOS is a good evaluation tool however, it cannot represent all of the complex interaction between the environment and the spilled materials (appendix C).
- ❖ The GTL diesel spill trajectory could not be modelled for Excravos River via GNOME due to Non availability and restriction policy of NOAA; for location files of Facility area (appendix G) outside the United States of America.
- ❖ Logistic constraint for accessing real time weather and river data of Excravos River area.
- ❖ Inability to get Excravos GTL plant SCP document for benchmarking purpose; due to audit, review and documentation process that is ongoing in Houston (Chris Peens, 2006).

4.2.8 FUTURE WORK and RECOMMENDATIONS

- ❖ Utilisation of site specific environmental data would infer greater credibility to interpretation in the environment; such data should be sourced and utilised for real-time and forecast planning for Excravos Terminal area.
- ❖ Industry operatives like Sasolchevron need to acquire real time meteorological data gathering capability around Excravos terminal for Contingency Planning and forecast effectiveness.
- ❖ Long time modelling should be attempted with wind and river data for span of 5 years and a comparison with observed spill field data around the area with link-up to a Geographic Information System database for efficient tracking.
- ❖ The acquisition and use of 'Spill Response Planning' Software should be adopted by oil companies and spill response contractors for the purpose of evaluating risk both in hindcast and forecast capacities.
- ❖ Early and rapid response system should be in place within an hour or less, in order to salvage reasonable volume of FT-diesel when spilt; having considered its quick disappearance rate in the open environment. This will ensure, reuse, impact prevention and reduction of remediation cost.

- Oil company research and the academia should carryout field observations to ascertain the extent of 'entrainment, dissolution, photo-oxidation and spreading of GTL diesel spills.

4.2.9 CONCLUSIONS FROM SIMULATION

Adequate and continuous planning is one of the most efficient means of effective spill response management system as addressed and modelled in the figure 4.1 which requires greater resources allocation.

Forecasts that are generated from computer aided simulations do assist Spill response Teams to improve on its ability to cope with likely impact of such a spill in the environment. By ensuring the right mix of resources are acquired, mobilised, and used when needed.

Improved management approach to oil spill response can definitely be enhanced by computer-based planning models (simulation) acquired by spill industry practitioners as a Business Re-engineering Strategy (BRS) in order to remain relevant and efficient in the oil and gas industry.

The simulated percent 'GTL diesel loss' versus 'Time after spill' derived from LSBF regression analysis technique for Excravos River (figure 4.3), as a chart should be an input into the Spill Contingency document for new plants as a guide for responders during response operation. This will aid decision-making process much easier to establish if and when resources are essential to combat spill.

The quick look estimation chart which will act as a prediction tool during field outings also can be used alone in the absence of real-time evaluation software. It is important for a more reliable 'Loss-Estimation–Chart' to be generated from historic data of the Excravos River area going back at least 5 years. This gives credence to the information and such charts should be reviewed periodically for consistency and reliability.

4.3 TRADE OFF ANALYSIS AND MODELS FOR GTL DIESEL CLEAN-UP

The 'Respond' (R1) stage during a typical oil spill response life cycle (figure 4.2) allows for lots of options to be considered. After an adequate containment for the purpose of recovering the product for reuse or clean-up of the impacted environment or controlling its trajectory is carried out. The objective definitely defines the choice of techniques applied.

It is now clear that the ultimate goal in oil spill response is prevention. However, its occurrence cannot be completely eliminated. This warrants the effort at reducing the impact ALARP. In-Situ burning (ISB) and conservational approach by use of natural materials seems to be a better way forward due to the numerous advantages they posses.

Presently, ISB is not frequently used, because of logistic (timing) challenges and the concern over air-borne pollution (French, 2001). Conversely, mechanical methods have always been used. Though with its consequent impact on the environment. Especially, in wetlands and saltwater mash ecosystems (Bryner et al, 2001). It is also on record that when none of these approaches are utilised, the environment suffers heavily from the toxicity effect from such diesels (French 2001; Bryner et al, 2001). Bryner et al's work also noted the thermal stress to plant in the environment due to in-situ burn which if uncontrolled below 60 °C leads to permanent damage. The minimisation of such impact from ISB can be eliminated by carrying out ISB technique in wetlands with at least 2cm of water layer above soil surface (Bryner et al, 2001; Lin et al, 2005a). Additionally, the research findings of Lin et al (2005b), shows the optimal temperature for safety of plant to be below 48 °C and water depth of 2cm below the soil surface significantly removes oil from the soil.

The efficiency of ISB method in swamp and sensitive environment is dependent on the effect on the ecosystem by the diesel. If harm is already done by virtue of toxicity, then ISB would give less opportunity for ecological regeneration. However, if the toxicity is negligible then ISB would have a less intrusive effect on the ecosystem than mechanical methods. The spotlight on GTL diesel spill tactically will eliminate worries due to toxicity.

Owens, (1999) has emphasised and encouraged the use if ISB approach as a reliable waste management strategy by minimising the quantity of waste generated compared to the use of mechanical methods. He advised its use more for very large scale spills involving oil in the open waters devoid of flooding season. ISB creates a rapid control strategy and near the source alternative (Owens, 1999) especially for sea going vessels with GTL diesel at risk of spillage and for facility spills that run-off into open waters.

The production of GTL diesel seems to arouse a critical look at ISB technique once more as a better option due to inherent properties of GTL diesel. This is elucidated by several close system research in motor engines where GTL diesel burns without soot formation and shows negligible coking of injector nozzles during combustions (GTL-LCA Synthesis Report, 2004; Sasol, 2007). Under normal circumstances, conventional diesel will burn to CO_2 and all the H_2 will burn to H_2O vapour with the presence of sulphur and particulate to form SO_2 and SO_3, on reaction with H_2O gives sulphuric acid and other sulphate compounds. Though, GTL diesel composition is nearly devoid of sulphur and particulate matter; such that the possible harm to the environment is greatly avoided during such burn.

Most conventional diesel has 25-35% of aromatic compounds in them which are known to provide greater energy per litre of fuels; yet, contributes to higher NO_x and SO_x and particulate emission to the environment (CONCAWE. 1996). GTL diesel on the other hand shows a complete contrast to these trends. GTL diesel has higher cetane number, ultra low sulphur content, negligible aromatics, and good cold flow characteristics (Sasol, 2007). These properties ensure a more efficient and cleaner-burning combustion environment that creates a substantial reduction in exhaust emissions, and reduced noise (Sasol, 2006, 2007).

The combustion of GTL diesel whether in combustion engine or in the open environment would be expected to show similar outcome; such that the benefits of such closed system research for GTL diesel can be achieved in ISB technique for dealing with spills with minimal effects.

The cold flow properties of GTL diesel would allow for quick and easier ignitability (very high cetane number: auto ignition) when other resources are threatened by the spill even if the environment is very cold. This also means that the diesel can be recovered much easily in very cold regions since the FT-diesel can remain liquid up to -18°C (pour point).

The quality of fuels such as GTL diesel has a direct influence on the level and kind of emissions associated with its combustion whether internal or external burn. The quality of the GTL diesel is determined by the composition of synthetic gas utilised in its production which is inclined to the quality of the raw material used and available refining technology utilised. This is further buttressed by Fingas et al. 1996 that "**The behaviour of oil in the environment is largely dictated by its chemical composition**" and the work of DEP, (2001) in Milkey, (2002) states "**...the composition of an individual petroleum product is a function of the origin and chemistry of the crude oil, the refining and blending processes and the use of additives**". In the same manner, the GTL diesel attributes in the environment (natural weathering or Human induced) is determined by the diesel properties due to its origin.

The understanding of this relationship allowed for the comparison between conventional diesel and GTL diesel by adopting the 'combustion curve model in Bartok (1983) as seen below.

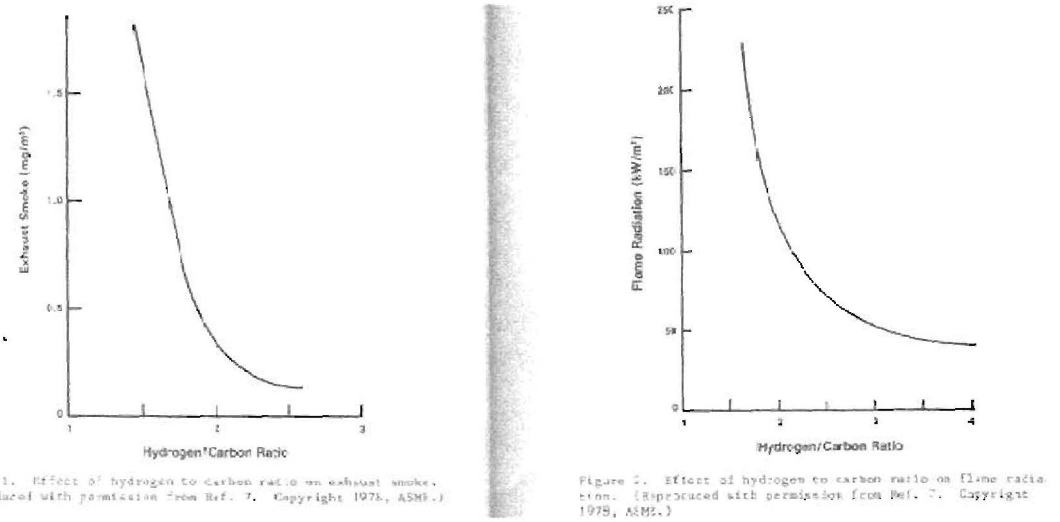
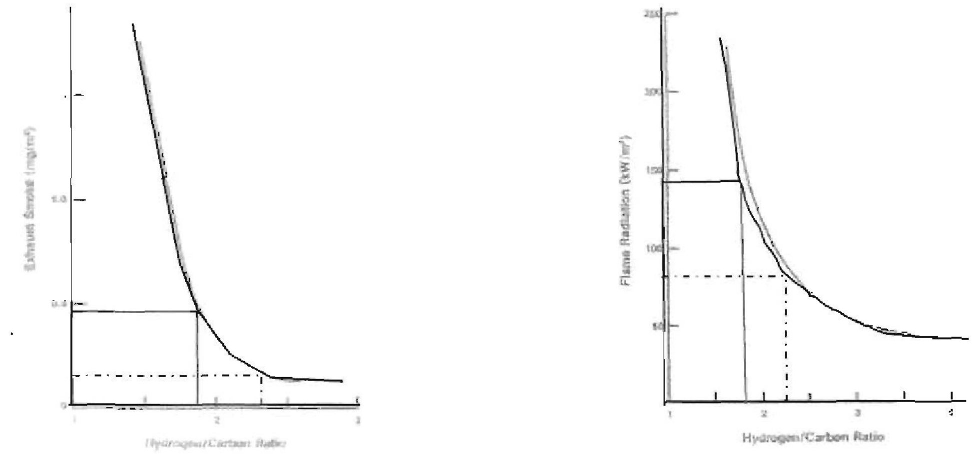


Figure 4.4: Bartok's Experimental Research curve on Synthetic fuels Emission.

A look at the synthetic gas data gathered from Sasol one site (ATR section) for complete one month shows the average H_2/CO ratio at 2.33 (Appendix I) and that of conventional diesel lies in the frame of 1.94 for H_2/CO ratio (Clark et al, 2003; Nannen, 2003). This synthetic gas is used for the production of GTL diesel. The plot of the 'Exhaust smoke and 'Flame radiation' versus 'Hydrogen-Carbon ratio' on 'the fuel combustion model' for both conventional diesel and GTL diesel confirms the superiority of the later (Figure 4.5).



X: Exhaust smoke Vs H/Co; Y: Flame Radiation Vs H/Co.
Conventional diesel ——— GTL diesel -·-·-·-·-
Figure 4.5: Comparative plots of Conventional and GTL diesel.

The plotting (figure 4.5) shows that GTL diesel would give less exhaust smoke and less smoke radiation relative to conventional diesels. Due to lower presence of aromatics, sulphur matter and heavy metals; conversely, the conventional diesel plot is seen to show the reverse trend. GTL fuels would exhibit lesser soot formation, lesser smoke emission, lesser luminosity, and reduced thermal radiation. This comparative outcome generally eliminates the earlier disadvantage of ISB technique except for external factor influence such as high sea waves, heavy rain and high wind speed conditions.

The transport fuels synthesised from natural gas origin have been observed to give outstanding superior and environmentally friendly products. Furthermore, all the unique properties of GTL diesel should encourage the greater use of ISB option for dealing with GTL diesel spills when not intended for reuse for the following reasons:

- ISB potentially prevents floating oil from drifting into and contaminating adjacent habitat and from penetrating into sediments (Bryner et al 2001; French 2001; Lin et al 2005a).

- ISB significantly removes diesel oil that had penetrated the sediment for all water depth (Lin et al 2005b).
- ISB contributes to reduction in the long-term impact of oil on benthic organisms (Lin et al 2005a, b).
- ISB requires less labour and equipment for execution (Breuel, 1981b; Owens, 1999).
- ISB is most suitable for large clean-up operations (Owens, 1999).
- ISB implementation produces relatively benign water and CO_2 (SASOL, 2007).
- ISB leads to significantly less waste and bye-products after clean-up operation (Owens, 1999).
- ISB technique creates a rapid control strategy and near the source alternative for very light fuels like GTL diesels (Owens, 1999).
- ISB also offers a quicker option of oil and oily debris disposal (CONCAWE, 1983b, 1996).
- ISB have been demonstrated to have higher effectiveness ratings, under certain conditions, than mechanical recovery (NOAA, 1992)
- ISB equipment requirement are more cost-effective because those response methods would result in greater mitigation of spill impacts than the addition of more mechanical recovery equipment (US-Federal Register, 2002)
- ISB of GTL diesel will eliminate concerns associated with toxicity and air pollution
- ISB of GTL diesel would create relatively no smoke plumes and soot and
- ISB of diesel on land would eliminate thermal stress with water laden soils during implementation (Bryner, 2001; Lin et al 2005a, b).

The focus of the scientific community in the area of environmental conservation is the use of natural materials for clean-up operation. This quest has led to research in finding materials that are effective as absorbents. These materials such as by-products of peat excavation, and cotton grass fibres (Suni et al 2004) can be utilised to curb small spills involving GTL diesels.

The conventional materials for clean-up have mostly been of synthetic nature and this pose problem for disposal. While with naturals materials this concern is eliminated. The findings show that cotton fibres have superior absorption properties of 2 to 3 times faster rate of absorption and 2 to 3 times more absorbed oil quantity than synthetic sorbents

(Suni et al 2004). Moreover, this material has low raw material cost, used effectively in removing diesel from surface water and undergo complete biodegration.

Another consideration of small spill clean-up for GTL diesel would be in 'Fuelling stations' where use of cotton fibre grass may not be convenient. The use of 'fuel absorbents' would serve. These materials do not absorb water and locks in the hydrocarbon to prevent further drips or stains. 'Absorbent doughnuts' can also be used when fuelling up car tanks, fuel pontoons and jerry cans (www.thegreenblue.org.uk/tradetalk/oilspills.asp). This action stops all the drips running down onto decks and into water.

GTL diesel dispensers at fuelling stations and consumers should be mandated to use these sorbent materials as a way of effectively controlling and preventing small spills. Sorbents at all time should also be kept in stock at such facilities.

Finally, the cost of clean-up and remediation needs to be trade-off with the overall net environmental benefit of the affected area. The cost of GTL diesel removal operations can be very difficult to predict prior to clean-up due to unique and dynamic variables of the environment. These factors can be placed into four major categories:

- Mobilisation: this involves the time (accessibility and trafficability) and cost involved in obtaining and moving support vessels, equipments, and personnel to and from site.
- Resources employed: this refers to acquisition and stocking of reliable and effective equipments and tools. Also, the daily cost of proficient personnel for clean-up operations.
- Clean-up duration: this is highly variable and unpredictable and is the time required to accomplish the work required.
- Disposal cost: this cost is as a result of the disposal activities carried out during clean-up operation, remediation activities and other miscellaneous expenditure from the oil spill operations.

The above factors determine the relative complexity of the recovery operations and clean-up carried out. Generally, the cost of clean-up is directly related to the complexity of the site and not necessarily on the volume of oil to be recovered.

It is here noted that the decision to recover GTL diesel spilt should be based on sound risk evaluation and well developed cost benefit analysis, because any salvage effort is usually expensive, time consuming and operationally challenging. This decision analysis of response should consider the potential environmental impact, socio-economic implication and modus operandi of environmental rehabilitation.

5.0 CHAPTER FIVE (SUMMARY and CONCLUSION)

5.1 DISCUSSIONS

The water-white and odourless characteristics of FT-diesel posses a form of challenge for oil spill responders and the general public at large. Apparently, it becomes very difficult to detect the presence of this spill due to its colourless nature and may be mistaken for water. This situation creates a favourable condition for explosion hazards and fire where sparks or cigarette stumps are nearby.

It then means that leaks and slicks of GTL diesel may go unnoticed for hours or days without been detected; by which time the damage to the aesthetics of the environment would have occurred. On the other hand, the non detection would have also led to loss of most valuable energy to the open environment. This when translated into cost implies a greater overhead cost and relative scarcity of product where and when required.

The possible way out of these circumstances would be to introduce dyes to the product to give it a distinctive colour and also infuse other chemical agent to improve nasal detection in the case of small, but incremental leaks. These actions will definitely help to mitigate other possible challenges that such GTL diesel spill would pose in the future.

GTL diesel may also impact negatively on the freshwater supply system of nearby human habitat where such spill may occur. This is actually possible with rupture or leakage of pipelines in such environment. Whether such pipelines are installed near surface as such easily preyed by vandals or buried deep into the subsurface away from vandals pose great risk.

An underground leak from subsurface pipeline has the capacity to affect the soil, groundwater quality, and proximal vegetations in the long-run. If the property of FT-diesels fuels of lightness, odourless, and colourless is anything to go bye, then the spill may move up and out to the surface of water bodies, or seep into low angle plains or depressions down stream. This soil inter-granular migration is possible when one considers for a fact that GTL diesel is lighter than water.

Moreover, the level and rate of infiltration of the FT-diesel into groundwater is dependent on the porosity, permeability, grain size, grain compaction and packing of soils around the spill area. This soaking effect on land and soils can contaminate water source making it unfit for consumption and if this goes unnoticed for a longtime, the diesel spilt would have travelled far and wide via the hydrology of the area impacting greater zones.

The realisation that FT-diesel when spilt would be difficult to recover with mechanical equipment and timely too, creates huge concern for the producers and entrepreneurs at large who are in business to make profit. It is then most likely that the option of reclaim and treat comes to mind to salvage the precious fluid. The method of applying gelling agent may promote reasonable recovery of the product after re-processing. However, it must be done immediately the spill occurs. Nonetheless, the cost of reprocessing combined with the initial cost of production per barrel would have to be weighed against other economic factors to determine if it is cost effective to do so or allow for destructive disposal.

The spilling of GTL diesel around farmlands may enable nutrient addition to such lands and farm owners should not necessarily perceive it in bad light. Soil enrichment by addition of fertilizers followed by tilling actions would in the long run enhance plant productivity. These approaches seem to be the best option available in such spill scenarios. This practice would favour most farmers who indulge in bush fallowing and rotational system of agriculture. However, produce from such farms immediately after the spill should be avoided except were toxicity report proves order wise. All these are made possible for the fact that FT-diesel is highly biodegradable, relatively non toxic and is synthesised to other useful soil nutrients.

The principle of being proactive can be implemented in the EGTL facility that is under construction by discerning the pre-staging points and planting trees of deep rooted nature within and around the river banks, docks and harbours during the early phase of the plant life span. These structures would act as an anchoring point across the channels for spill control and containment. Alternatively, reinforced concrete columns may be cast in place or pilled into such discerned spots as mooring positions for booms.

Still within the proactive spirit, exclusion booming around river mouth should be encouraged like in Qatar (Ras-lafan) and Nigeria (Excravos River). It will help to prevent impending spill dispersion of FT-diesel to or from the sea. These booms are expected to be pre-staged in position in preparedness. Although, such exclusion booming around harbours and river mouth, like in Excravos may likely pose logistic difficulty for operational vessels and boats around the terminal port.

The booming should be fashioned in such a way that vessels pathway is not obstructed. The option of a hydraulically controlled water gates attached with these booms can be designed and installed around the harbour and river mouth without disrupting the river dynamics. This booming system could also serve to control tidal fluctuations that might disturb harbour activities. A boom of choice in the interim is a flexible curtain type boom for its favourable response to tidal changes. It can also be modified to have absorption tendrils for greater capture of GTL diesel when spilt.

5.2 SUMMARY

The build up to this dissertation asked the questions of how do we 'improve the oil spill response initiatives on new and varied products such as the GTL diesel fuels of natural gas origin?'. Literature review has shown that such spills possibly will occur either by accident or intentionally and numerous factors are seen to be responsible for this situation.

The understanding of the properties of GTL diesel is the first step in the right direction. However, literature overview did show paucity of the certain characteristics of GTL diesel with respect to spill response such as coefficient of dispersion, interfacial tendency, emulsification tendency and stability; and water content.

A GTL diesel has an outstanding quality of lightness, been colourless, and odourless; virtually free of sulphur, aromatics, and heavy metals; higher cetane number, very low pour point, and outstanding cold flow properties. On combustion it has a high thermal stability, low radiation temperature, absence of soot formation and absence of ash content. Above all FT-diesel is a saturated hydrocarbon, highly paraffinic, with higher hydrogen content relative to conventional diesels. Moreover, they are known to be non toxic, highly biodegradable and environmentally benign.

The spill response industry may wish to overlook the continuous need for effective spill response action due to the environmental plus of such GTL diesels coupled with neglect to the industry due to rare occurrence of large spills and probable disregard for smaller spills in recent times.

The consideration of the precious nature of such fuels should continue to spur spiller companies and response operative “to improvement in response approaches” for the sake of

- preventing financial loss of a very scarce and highly needed energy product,
- non disruption of operations,
- sustaining cleaner environmental emissions,
- protecting habitat aesthetics,
- sustaining clean fresh water quality and supply,
- Making energy readily available,
- ensuring investors satisfaction,
- re-establishing corporate and social confidence on the spiller-responder and
- Ensuring research continuity that continuously informs policies and regulations.

Many spill response contractors and spiller organisation have remained in the reactive seat for a long time and this is making the oil spill response industry look dogmatic and seems to lack importance. However, with a clear identification of the nature of services rendered on the spill response life cycle via the PERREP model would help in revitalising their relevance.

An evaluation of GTL diesel spill by use of ADIOS software simulations and LSBF regression modelling techniques have been seen to enhance adequate planning as an improved management approach in staying ahead. The outcomes show that dispersion is the most influential weathering process likely to affect GTL diesel spills with 36 to 41% of it evaporating within 24 hours of spill. Moreover, the chance of an economic salvage of such product lies in the first hour after spill. This effort has also led us to the development of a ‘quick-look-estimation chart’ for determining the quantity of GTL diesel that could be lost with time on been spilt.

Industry operatives should focus their strength and resources on activities and services that ensures continuous ‘planning’ products and be involved more with ‘evaluation’ and ‘enhancement’ services which is the best way to respond in the new scheme of things.

In the event of such FT-diesel spills occurring, certain methods could suffice mitigation. They include tilling and mixing; fertilizer application and Bioaugmentation; use of cotton fibre grass absorbent materials; in-situ burning practice; use of pumps and skimmers of compatible nature like belt skimmers with fuzzy polymer fabrics and standard nitrile materials. On a smaller scale drum and mop skimmers could serve.

The centre of attention should be targeted on new and upcoming GTL plants, pipeline operations, transport vessels and all transfer windows to achieve effective response. Preventing spill is the best way to respond to spillage by adopting an Integrated Contingency Plan. This can best be attained by the right mix of regulatory and voluntary compliance initiative together with a systematic compilation and analysis of historical data and information relevant to spill science. Regular documentation of small spill incidents and increased awareness should be promoted among operatives.

5.3 RESEARCH CONSTRAINTS AND RECOMMENDATIONS

The limiting factors in this dissertation are as follows:

- One of the unresolved challenges was the inability to obtain the SCP document of ChevronTexaco for the GTL plant due to its drafting stage and confidentiality issue. And also that of Shell Malaysia SCP for a similar plant due to accessibility. This made it difficult to carry out benchmarking study on the elements of the organisations SCP provisions against BMP.
- Paucity of research data on the properties of GTL diesel with respect to spill clean-up and non availability of GTL data in spill software data files.
- Non availability of Excravos River map from NOAA in GNOME database due to policy issues for spill-trajectory and resources-at-risk simulation.
- Spill involving GTL diesel has never happened, as such the difficulty to compare it with its likes for the purpose of validation and verification. The only way forward could be seen to be laboratory analysis in the interim; this however, is near impossible since most plants operating are in test stages and as such regards its information as classified for academic purpose.

My advice would be as follows:

- It is important for the spill response industry practitioners to come together and unify the nomenclature for Oil Spill Classification in order to avoid confusion.
- The health and safety aspect to responders need to be examined critically while cleaning up GTL diesel.
- A comprehensive character portfolio need to be assembled into standard format in ADIOS and other related software packages for GTL diesel and other synthetic products.
- Long time modelling should be attempted with wind and river data for span of 5 years and a comparison with observed spill field data around the Excravos River area.
- The effect and impact of GTL diesel on the flora and fauna should be carried out to ascertain level of impact if any especially in fresh water habitat.
- Physical testing of the level of weathering on the open waters need to be carried out for GTL products around Excravos River in other to compare and predict mass balance against computer aided simulations.
- Research should be carried out for penetration rate of GTL diesel into the soil and monitoring wells should be dug around the Excravos terminal facility for underground water quality checks. This would allow for continuous evaluation against contamination.
- The development and drafting of SCP for new and upcoming GTL plants should incorporate the protection of local cultural resources in the area throughout the plants span by promoting education, monitoring and protective ventures.
- The EGTL plant should have an Oil spill response Coordinating Office in-Situ with an Integrated Spill Contingency Plan (ISCP) document as an operational guide.
- GTL facilities should acquire the latest state of the art surveillance and tracking devices which should be linked up by satellite and GIS systems.
- The acquisition and use of 'Spill Response Planning' Software should be adopted by oil companies and spill response contractors for the purpose of evaluating risk both in hindcast and forecast capacities.
- Soil and water bodies around GTL diesel plant should be subjected to microbial analysis to determine indigenous microbes and its distribution. This will help to decide appropriate remediation strategies were needed. This microbial analysis should be addressed in the SCP as well.

- A rehabilitative strategy should be set-up around GTL facility by way of a nursery to grow mangroves and sensitive vegetations as a transplant programme initiative in preparation for eventuality.
- Early and rapid response system should be in place within an hour or less, in order to salvage reasonable volume of FT-diesel when spilt.
- The oil spill response industry operatives should identify their response life cycle position and re-orient its objective to services that creates planning and preventive outputs.
- Oil company research teams and the academia should carry out field observations to ascertain the extent of ‘entrainment, dissolution, photo-oxidation and spreading of GTL diesel spills.
- The advent of GTL diesels should promote the use of ISB, fertilizer application, tilling and Bioaugmentation techniques, and discourage the use of dispersants and chemical agents in its clean-up.

5.4 CLOSURE

Oil spill response is very much a technical business and managing such activities or processes effectively in 21st century requires a great deal of technological input and professionalism. Looking forward, the spill response industry should embrace these innovations to be relevant.

On the other hand, continuous improvement would be seen as the only way to score points and this should take the researcher a step further at a doctoral level to discern the EGTL case study in terms of implementation and detailed EGTL diesel character analysis for effective response.

Finally, the implementation, further study and research opportunity has thus been promoted by accolades from EGTL management (Appendix J) to enhance excellence in the spill response system of EGTL project.

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Appendix A: Glossary of Terms

TERM DEFINITION

Ballast Tanks: special tanks on large ships that are used to provide stability needed when carrying less than a full load of cargo and to keep the ship at the proper depth in the water.
Berm: a terrace formed by wave action along the backshore of a beach; a mound or wall of earth, sand or rocks used as a barrier or as insulation.
Bio-degradation (or **Biodegrade**): the breaking down of substances by micro-organisms, like bacteria, which use the substances for food and generally release harmless by-products such as carbon dioxide and water.
Boom: a temporary floating barrier used to contain an oil spill.
Cetane: A measure of the auto-ignition potential of fuels. Cetane number (CN) is a dimensionless descriptor of the ignition quality of the diesel fuel (DF).
Density: A description of oil by some measurement of its volume to weight ratio. The industry usually relies on two expressions of oil's volume-weight relationship-specific gravity and API degrees. The larger a specific gravity number and the smaller an API number, the denser the oil.
Dispersion : the distribution of spilled oil into the upper layer of the water column by natural wave action or application of chemical dispersants.
Dispersant: chemical that causes oil to break into small droplets by reducing the surface tension between the water and oil. It is used to clean-up low viscosity oils, yet it impacts the plankton in the upper water layers, because the oil is dispersed within the water.
Evaporation (or **"to evaporate"**): the physical change by which any substance is converted from a liquid to a vapour or gas.
Fahrenheit degrees (F): A temperature scale according to which water boils at 212 and freezes at 32 Fahrenheit degrees. Convert to Centigrade degrees (C) by the following formula: (F-32)/1.8= C.
Fireproof booms: means an oil containment boom constructed out of fireproof materials and designed to withstand prolonged periods of exposure to heat and flame during in-situ burning operations and have a demonstrated service life that extends through multiple days of burning operations.
Fire-resistant boom: means an oil containment boom constructed out of fire-retardant fabrics and reinforced internal strength members and designed to withstand exposure to heat and flame during in-situ burning for one operational day.
Fecundity: Lower number of ovaries per polyp, fewer larvae per coral head, and lower settlement rate of planulae.
Impoundment Spill control for tank: content designed to limit the liquid travel in case of release. May also refer to spill control for LNG piping or transfer operations.
Intertidal Zone: On a beach, the area between high tide and low tide.
Leach: To draw out or remove the oil from the soil or sediments, often a result of the action or percolation of water.
Middle distillates: Products heavier than motor gasoline/naphtha and lighter than residual fuel oil. This range includes heating oil, diesel, kerosene, and jet kero.
Mole Percent Mole: is a short form of molecular weight. Mole fraction or mole percent is the number of moles of a component of a mixture divided by the total number of moles in the mixture.
Model: an abstraction or simplification of a natural phenomenon developed to predict a new phenomenon or to provide insight into existing ones.

NOAA: the National Oceanic and Atmospheric Administration (NOAA), an agency of the U.S. government that conducts research and gathers data about the global oceans, atmosphere, space, and sun, and applies this knowledge to science.**Oil Slick**: a layer of oil floating on the surface of water.
Oleophilic: having a strong affinity for lipids, including petroleum oils and fats. Oleophilic materials absorb or stick to petroleum oils.
Photo-Oxidation: sunlight-promoted chemical reaction of oxygen in the air and oil
Recovery: the act, process or instance of bringing a habitat or ecosystem back to a normal condition; or to save it from loss and restore it to usefulness.
Remedial: intended as a treatment or correction.
Restoration: bringing back or restoring species and ecosystems after human disturbance.
Stranded Gas: Gas is considered stranded when it is not near its customer and a pipeline is not economically justified.
Skimmers: devices used to remove oil from the water's surface.
Sorbents: substances that take up and hold water or oil; sorbents used in oil spill clean-up are made of oleophilic materials.
Stressor: the five external forces (i.e. stressors) identified as affecting coastal and marine ecosystems are pollution, invasive species, climate change, extreme events, and land or resource use.
Subtidal: the coastal life zone that remains underwater (below low tide), but above the continental shelf.
Trajectory Model: a prediction about the path of something—like oil slick.
Viscosity (or **Viscous**): amount of resistance to flow by a liquid. Corn syrup is much more *viscous* than water. High molecular weight oils have high viscosity (i.e. do not flow easily).
Visqueen: a plastic sheet of impermeable material used to prevent leaks of oil into underground sediments or away from containment
Weathering: action of the wind, waves, and water on a substance, such as oil, that leads to disintegration or deterioration of the substance.

APPENDIX B: SPCC Plan Requirements for Onshore Facilities.

Title 40: Protection of Environment

PART 112—OIL POLLUTION PREVENTION

Subpart B—Requirements for Petroleum Oils and Non-Petroleum Oils, Except Animal Fats and Oils and Greases, and Fish and Marine Mammal Oils; and Vegetable Oils (Including Oils from Seeds, Nuts, Fruits, and Kernels)

§ 112.7 General requirements for Spill Prevention, Control, and Counter-measure Plans.

If you are the owner or operator of a facility subject to this part you must prepare a Plan in accordance with good engineering practices. The Plan must have the full approval of management at a level of authority to commit the necessary resources to fully implement the Plan. You must prepare the Plan in writing. If you do not follow the sequence specified in this section for the Plan, you must prepare an equivalent Plan acceptable to the Regional Administrator that meets all of the applicable requirements listed in this part, and you must supplement it with a section cross-referencing the location of requirements listed in this part and the equivalent requirements in the other prevention plan. If the Plan calls for additional facilities or procedures, methods, or equipment not yet fully operational, you must discuss these items in separate paragraphs, and must explain separately the details of installation and operational start-up. As detailed elsewhere in this section, you must also:

(a)(1) Include a discussion of your facility's conformance with the requirements listed in this part.

(2) Comply with all applicable requirements listed in this part. Except as provided in §112.6, your Plan may deviate from the requirements in paragraphs (g), (h)(2) and (3), and (i) of this section and the requirements in subparts B and C of this part, except the secondary containment requirements in paragraphs (c) and (h)(1) of this section, and §§112.8(c)(2), 112.8(c)(11), 112.9(c)(2), 112.10(c), 112.12(c)(2), and 112.12(c)(11), where applicable to a specific facility, if you provide equivalent environmental protection by some other means of spill prevention, control, or counter-measure. Where your Plan does not conform to the applicable requirements in paragraphs (g), (h)(2) and (3), and (i) of this section, or the requirements of subparts B and C of this part, except the secondary containment requirements in paragraph (c) and (h)(1) of this section, and §§112.8(c)(2), 112.8(c)(11), 112.9(c)(2), 112.10(c), 112.12(c)(2), and 112.12(c)(11), you must state the reasons for nonconformance in your Plan and describe in detail alternate methods and how you will achieve equivalent environmental protection. If the Regional Administrator determines that the measures described in your Plan do not provide equivalent environmental protection, he may require that you amend your Plan, following the procedures in §112.4(d) and (e).

(3) Describe in your Plan the physical layout of the facility and include a facility diagram, which must mark the location and contents of each container. The facility diagram must include completely buried tanks that are otherwise exempted from the requirements of this part under §112.1(d)(4). The facility diagram must also include all transfer stations and connecting pipes. You must also address in your Plan:

(i) The type of oil in each container and its storage capacity;

(ii) Discharge prevention measures including procedures for routine handling of products (loading, unloading, and facility transfers, etc.);

(iii) Discharge or drainage controls such as secondary containment around containers and other structures, equipment, and procedures for the control of a discharge;

(iv) Counter-measures for discharge discovery, response, and clean-up (both the facility's capability and those that might be required of a contractor);

(v) Methods of disposal of recovered materials in accordance with applicable legal requirements; and

(vi) Contact list and phone numbers for the facility response coordinator, National Response Centre, clean-up contractors with whom you have an agreement for response, and all appropriate Federal, State, and local agencies who must be contacted in case of a discharge as described in §112.1(b).

(4) Unless you have submitted a response plan under §112.20, provide information and procedures in your Plan to enable a person reporting a discharge as described in §112.1(b) to relate information on the exact address or location and phone number of the facility; the date and time of the discharge, the type of material discharged; estimates of the total quantity discharged; estimates of the quantity discharged as described in §112.1(b); the source of the discharge; a description of all affected media; the cause of the discharge; any damages or injuries caused by the discharge; actions being used to stop, remove, and mitigate the effects of the discharge; whether an evacuation may be needed; and, the names of individuals and/or organisations who have also been contacted.

(5) Unless you have submitted a response plan under §112.20, organise portions of the Plan describing procedures you will use when a discharge occurs in a way that will make them readily usable in an emergency, and include appropriate supporting material as appendices.

(b) Where experience indicates a reasonable potential for equipment failure (such as loading or unloading equipment, tank overflow, rupture, or leakage, or any other equipment known to be a source of a discharge), include in your Plan a prediction of the direction, rate of flow, and total quantity of oil which could be discharged from the facility as a result of each type of major equipment failure.

(c) Provide appropriate containment and/or diversionary structures or equipment to prevent a discharge as described in §112.1(b), except as provided in paragraph (k) of this section for qualified oil-filled operational equipment. The entire containment system, including walls and floor, must be capable of containing oil and must be constructed so that any discharge from a primary containment system, such as a tank or pipe, will not escape the containment system before clean-up occurs. At a minimum, you must use one of the following prevention systems or its equivalent:

(1) For onshore facilities:

(i) Dikes, berms, or retaining walls sufficiently impervious to contain oil;

(ii) Curbing;

(iii) Culverting, gutters, or other drainage systems;

(iv) Weirs, booms, or other barriers;

(v) Spill diversion ponds;

(vi) Retention ponds; or

(vii) Sorbent materials.

(2) For offshore facilities:

(i) Curbing or drip pans; or

(ii) Sumps and collection systems.

(d) Provided your Plan is certified by a licenced Professional Engineer under §112.3(d), or, in the case of a qualified facility that meets the criteria in §112.3(g), the relevant sections of your Plan are certified by a licenced Professional Engineer under §112.6(d), if you determine that the installation of any of the structures or pieces of equipment listed in paragraphs (c) and (h)(1) of this section, and §§112.8(c)(2), 112.8(c)(11), 112.9(c)(2), 112.10(c), 112.12(c)(2), and 112.12(c)(11) to prevent a discharge as described in §112.1(b) from any onshore or offshore facility is not practicable, you must clearly explain in your Plan why such measures are not practicable; for bulk storage containers, conduct both periodic integrity testing of the containers and periodic integrity and leak testing of the valves and piping; and, unless you have submitted a response plan under §112.20, provide in your Plan the following:

(1) An oil spill contingency plan following the provisions of part 109 of this chapter.

(2) A written commitment of manpower, equipment, and materials required to expeditiously control and remove any quantity of oil discharged that may be harmful.

(e) *Inspections, tests, and records.* Conduct inspections and tests required by this part in accordance with written procedures that you or the certifying engineer develop for the facility. You must keep these written procedures and a record of the inspections and tests, signed by the appropriate supervisor or inspector, with the SPCC Plan for a period of three years. Records of inspections and tests kept under usual and customary business practices will suffice for purposes of this paragraph.

(f) *Personnel, training, and discharge prevention procedures.* (1) At a minimum, train your oil-handling personnel in the operation and maintenance of equipment to prevent discharges; discharge procedure protocols; applicable pollution control laws, rules, and regulations; general facility operations; and, the contents of the facility SPCC Plan.

(2) Designate a person at each applicable facility who is accountable for discharge prevention and who reports to facility management.

(3) Schedule and conduct discharge prevention briefings for your oil-handling personnel at least once a year to assure adequate understanding of the SPCC Plan for that facility. Such briefings must highlight and describe known discharges as described in §112.1(b) or failures, malfunctioning components, and any recently developed precautionary measures.

(g) *Security (excluding oil production facilities).* (1) Fully fence each facility handling, processing, or storing oil, and lock and/or guard entrance gates when the facility is not in production or is unattended.

(2) Ensure that the master flow and drain valves and any other valves permitting direct outward flow of the container's contents to the surface have adequate security measures so that they remain in the closed position when in non-operating or non-standby status.

(3) Lock the starter control on each oil pump in the "off" position and locate it at a site accessible only to authorised personnel when the pump is in a non-operating or non-standby status.

(4) Securely cap or blank-flange the loading/unloading connections of oil pipelines or facility piping when not in service or when in standby service for an extended time. This security practice also applies to piping that is emptied of liquid content either by draining or by inert gas pressure.

(5) Provide facility lighting commensurate with the type and location of the facility that will assist in the:

(i) Discovery of discharges occurring during hours of darkness, both by operating personnel, if present, and by non-operating personnel (the general public, local police, etc.); and

(ii) Prevention of discharges occurring through acts of vandalism.

(h) *Facility tank car and tank truck loading/unloading rack (excluding offshore facilities).* (1) Where loading/unloading area drainage does not flow into a catchment basin or treatment facility designed to handle discharges, use a quick drainage system for tank car or tank truck loading and unloading areas. You must design any containment system to hold at least the maximum capacity of any single compartment of a tank car or tank truck loaded or unloaded at the facility.

(2) Provide an interlocked warning light or physical barrier system, warning signs, wheel chocks, or vehicle break interlock system in loading/unloading areas to prevent vehicles from departing before complete disconnection of flexible or fixed oil transfer lines.

(3) Prior to filling and departure of any tank car or tank truck, closely inspect for discharges the lowermost drain and all outlets of such vehicles, and if necessary, ensure that they are tightened, adjusted, or replaced to prevent liquid discharge while in transit.

(i) If a field-constructed aboveground container undergoes a repair, alteration, reconstruction, or a change in service that might affect the risk of a discharge or failure due to brittle fracture or other catastrophe, or has discharged oil or failed due to brittle fracture failure or other catastrophe, evaluate the container for risk of discharge or failure due to brittle fracture or other catastrophe, and as necessary, take appropriate action.

(j) In addition to the minimal prevention standards listed under this section, include in your Plan a complete discussion of conformance with the applicable requirements and other effective discharge prevention and containment procedures listed in this part or any applicable more stringent State rules, regulations, and guidelines.

(k) *Qualified Oil-filled Operational Equipment.* The owner or operator of a facility with oil-filled operational equipment that meets the qualification criteria in paragraph (k)(1) of this sub-section may choose to implement for this qualified oil-filled operational equipment the alternate requirements as described in paragraph (k)(2) of this sub-section in lieu of general secondary containment required in paragraph (c) of this section.

(1) *Qualification Criteria—Reportable Discharge History:* The owner or operator of a facility that has had no single discharge as described in §112.1(b) from any oil-filled operational equipment exceeding 1,000 U.S. gallons or no two discharges as described in §112.1(b) from any oil-filled operational equipment each exceeding 42 U.S. gallons within any twelve month period in the three years prior to the SPCC Plan certification date, or since becoming subject to this part if the facility has been in operation for less than three years (other than oil discharges as described in §112.1(b) that are the result of natural disasters, acts of war or terrorism); and

(2) *Alternative Requirements to General Secondary Containment.* If secondary containment is not provided for qualified oil-filled operational equipment pursuant to paragraph (c) of this section, the owner or operator of a facility with qualified oil-filled operational equipment must:

(i) Establish and document the facility procedures for inspections or a monitoring programme to detect equipment failure and/or a discharge; and

(ii) Unless you have submitted a response plan under §112.20, provide in your Plan the following:

(A) An oil spill contingency plan following the provisions of part 109 of this chapter.

(B) A written commitment of manpower, equipment, and materials required to expeditiously control and remove any quantity of oil discharged that may be harmful.

[67 FR 47140, July 17, 2002, as amended at 71 FR 77292, Dec. 26, 2006]: a

§ 112.8 Spill Prevention, Control, and Counter-measure Plan requirements for onshore facilities (excluding production facilities).

If you are the owner or operator of an onshore facility (excluding a production facility), you must:

(a) Meet the general requirements for the Plan listed under §112.7, and the specific discharge prevention and containment procedures listed in this section.

(b) *Facility drainage.* (1) Restrain drainage from diked storage areas by valves to prevent a discharge into the drainage system or facility effluent treatment system, except where facility systems are designed to control such discharge. You may empty diked areas by pumps or ejectors; however, you must manually activate these pumps or ejectors and must inspect the condition of the accumulation before starting, to ensure no oil will be discharged.

(2) Use valves of manual, open-and-closed design, for the drainage of diked areas. You may not use flapper-type drain valves to drain diked areas. If your facility drainage drains directly into a watercourse and not into an on-site wastewater treatment plant, you must inspect and may drain uncontaminated retained stormwater, as provided in paragraphs (c)(3)(ii), (iii), and (iv) of this section.

(3) Design facility drainage systems from undiked areas with a potential for a discharge (such as where piping is located outside containment walls or where tank truck discharges may occur outside the loading area) to flow into ponds, lagoons, or catchment basins designed to retain oil or return it to the facility. You must not locate catchment basins in areas subject to periodic flooding.

(4) If facility drainage is not engineered as in paragraph (b)(3) of this section, equip the final discharge of all ditches inside the facility with a diversion system that would, in the event of an uncontrolled discharge, retain oil in the facility.

(5) Where drainage waters are treated in more than one treatment unit and such treatment is continuous, and pump transfer is needed, provide two "lift" pumps and permanently install at least one of the pumps. Whatever techniques you use, you must engineer facility drainage systems to prevent a discharge as described in §112.1(b) in case there is an equipment failure or human error at the facility.

(c) *Bulk storage containers.* (1) Not use a container for the storage of oil unless its material and construction are compatible with the material stored and conditions of storage such as pressure and temperature.

(2) Construct all bulk storage tank installations (except mobile refuelers) so that you provide a secondary means of containment for the entire capacity of the largest single container and sufficient freeboard to contain precipitation. You must ensure that diked areas are sufficiently impervious to contain discharged oil. Dikes, containment curbs, and pits are commonly employed for this purpose. You may also use an alternative system consisting of a drainage trench enclosure that must be arranged so that any discharge will terminate and be safely confined in a facility catchment basin or holding pond.

(3) Not allow drainage of uncontaminated rainwater from the diked area into a storm drain or discharge of an effluent into an open watercourse, lake, or pond, bypassing the facility treatment system unless you:

(i) Normally keep the bypass valve sealed closed.

(ii) Inspect the retained rainwater to ensure that its presence will not cause a discharge as described in §112.1(b).

(iii) Open the bypass valve and reseal it following drainage under responsible supervision; and

(iv) Keep adequate records of such events, for example, any records required under permits issued in accordance with §§122.41(j)(2) and 122.41(m)(3) of this chapter.

(4) Protect any completely buried metallic storage tank installed on or after January 10, 1974 from corrosion by coatings or cathodic protection compatible with local soil conditions. You must regularly leak test such completely buried metallic storage tanks.

(5) Not use partially buried or bunkered metallic tanks for the storage of oil, unless you protect the buried section of the tank from corrosion. You must protect partially buried and bunkered tanks from corrosion by coatings or cathodic protection compatible with local soil conditions.

(6) Test each aboveground container for integrity on a regular schedule, and whenever you make material repairs. The frequency of and type of testing must take into account container size and design (such as floating roof, skid-mounted, elevated, or partially buried). You must combine visual inspection with another testing technique such as hydrostatic testing, radiographic testing, ultrasonic testing, acoustic emissions testing, or another system of non-destructive shell testing. You must keep comparison records and you must also inspect the container's supports and foundations. In addition, you must frequently inspect the outside of the container for signs of deterioration, discharges, or accumulation of oil inside diked areas. Records of inspections and tests kept under usual and customary business practices will suffice for purposes of this paragraph.

(7) Control leakage through defective internal heating coils by monitoring the steam return and exhaust lines for contamination from internal heating coils that discharge into an open watercourse, or pass the steam return or exhaust lines through a settling tank, skimmer, or other separation or retention system.

(8) Engineer or update each container installation in accordance with good engineering practice to avoid discharges. You must provide at least one of the following devices:

(i) High liquid level alarms with an audible or visual signal at a constantly attended operation or surveillance station. In smaller facilities an audible air vent may suffice.

(ii) High liquid level pump cutoff devices set to stop flow at a predetermined container content level.

(iii) Direct audible or code signal communication between the container gauger and the pumping station.

(iv) A fast response system for determining the liquid level of each bulk storage container such as digital computers, telepulse, or direct vision gauges. If you use this alternative, a person must be present to monitor gauges and the overall filling of bulk storage containers.

(v) You must regularly test liquid level sensing devices to ensure proper operation.

(9) Observe effluent treatment facilities frequently enough to detect possible system upsets that could cause a discharge as described in §112.1(b).

(10) Promptly correct visible discharges which result in a loss of oil from the container, including but not limited to seams, gaskets, piping, pumps, valves, rivets, and bolts. You must promptly remove any accumulations of oil in diked areas.

(11) Position or locate mobile or portable oil storage containers to prevent a discharge as described in §112.1(b). Except for mobile refuelers, you must furnish a secondary means of containment, such as a dike or catchment basin, sufficient to contain the capacity of the largest single compartment or container with sufficient freeboard to contain precipitation.

(d) *Facility transfer operations, pumping, and facility process.* (1) Provide buried piping that is installed or replaced on or after August 16, 2002, with a protective wrapping and coating. You must also cathodically protect such buried piping installations or otherwise satisfy the corrosion protection standards for piping in part 280 of this chapter or a State programme approved under part 281 of this chapter. If a section of buried line is exposed for any reason, you must carefully inspect it for deterioration. If you find corrosion damage, you must undertake additional examination and corrective action as indicated by the magnitude of the damage.

(2) Cap or blank-flange the terminal connection at the transfer point and mark it as to origin when piping is not in service or is in standby service for an extended time.

(3) Properly design pipe supports to minimise abrasion and corrosion and allow for expansion and contraction.

(4) Regularly inspect all aboveground valves, piping, and appurtenances. During the inspection you must assess the general condition of items, such as flange joints, expansion joints, valve glands and bodies, catch pans, pipeline supports, locking of valves, and metal surfaces. You must also conduct integrity and leak testing of buried piping at the time of installation, modification, construction, relocation, or replacement.

(5) Warn all vehicles entering the facility to be sure that no vehicle will endanger aboveground piping or other oil transfer operations.

[67 FR 47146, July 17, 2002, as amended at 71 FR 77293, Dec. 26, 2006] :a

§ 112.9 Spill Prevention, Control, and Counter-measure Plan requirements for onshore oil production facilities.

If you are the owner or operator of an onshore production facility, you must:

(a) Meet the general requirements for the Plan listed under §112.7, and the specific discharge prevention and containment procedures listed under this section.

(b) *Oil production facility drainage.* (1) At tank batteries and separation and treating areas where there is a reasonable possibility of a discharge as described in §112.1(b), close and seal at all times drains of dikes or drains of equivalent measures required under §112.7(c)(1), except when draining uncontaminated rainwater. Prior to drainage, you must inspect the diked area and take action as provided in §112.8(c)(3)(ii), (iii), and (iv). You must remove accumulated oil on the rainwater and return it to storage or dispose of it in accordance with legally approved methods.

(2) Inspect at regularly scheduled intervals field drainage systems (such as drainage ditches or road ditches), and oil traps, sumps, or skimmers, for an accumulation of oil that may have resulted from any small discharge. You must promptly remove any accumulations of oil.

(c) *Oil production facility bulk storage containers.* (1) Not use a container for the storage of oil unless its material and construction are compatible with the material stored and the conditions of storage.

(2) Provide all tank battery, separation, and treating facility installations with a secondary means of containment for the entire capacity of the largest single container and sufficient freeboard to contain precipitation. You must safely confine drainage from undiked areas in a catchment basin or holding pond.

(3) Periodically and upon a regular schedule visually inspect each container of oil for deterioration and maintenance needs, including the foundation and support of each container that is on or above the surface of the ground.

(4) Engineer or update new and old tank battery installations in accordance with good engineering practice to prevent discharges. You must provide at least one of the following:

(i) Container capacity adequate to assure that a container will not overfill if a pumper/gauger is delayed in making regularly scheduled rounds.

(ii) Overflow equalising lines between containers so that a full container can overflow to an adjacent container.

(iii) Vacuum protection adequate to prevent container collapse during a pipeline run or other transfer of oil from the container.

(iv) High level sensors to generate and transmit an alarm signal to the computer where the facility is subject to a computer production control system.

(d) *Facility transfer operations, oil production facility.* (1) Periodically and upon a regular schedule inspect all aboveground valves and piping associated with transfer operations for the general condition of flange joints, valve glands and bodies, drip pans, pipe supports, pumping well polish rod stuffing boxes, bleeder and gauge valves, and other such items.

(2) Inspect saltwater (oil field brine) disposal facilities often, particularly following a sudden change in atmospheric temperature, to detect possible system upsets capable of causing a discharge.

(3) Have a programme of flowline maintenance to prevent discharges from each flowline.

§ 112.10 Spill Prevention, Control, and Counter-measure Plan requirements for onshore oil drilling and workover facilities.

If you are the owner or operator of an onshore oil drilling and workover facility, you must:

(a) Meet the general requirements listed under §112.7, and also meet the specific discharge prevention and containment procedures listed under this section.

(b) Position or locate mobile drilling or workover equipment so as to prevent a discharge as described in §112.1(b).

(c) Provide catchment basins or diversion structures to intercept and contain discharges of fuel, crude oil, or oily drilling fluids.

(d) Install a blowout prevention (BOP) assembly and well control system before drilling below any casing string or during workover operations. The BOP assembly and well control system must be capable of controlling any well-head pressure that may be encountered while that BOP assembly and well control system are on the well.

Source: (http://ecfr.gpoaccess.gov/cgi/t/text/text-idx?c=ecfr;sid=43fa4cc3f149b80e2caab5c1b8b84823;rgn=div5;view=text;node=40%3A21.0.1.1.7;idno=40;cc=ecfr) date of access: 8th May, 2007.

APPENDIX C: Simulation and Modelling Software- ADIOS.

ADIOS2

ADIOS2 (Automated Data Inquiry for Oil Spills) is an oil weathering model that runs both on Macintosh computers and in Windows. ADIOS2 incorporates a database containing more than a thousand crude oils and refined products, and provides quick estimates of the expected characteristics and behaviour of oil spilled into the marine environment. Automated Data Inquiry for Oil Spills (ADIOS2) is an oil spill response tool to assist oil spill responders and contingency planners in making decisions on potential response strategies.

The predictions it makes, presented as both graphics and text, are designed to help answer questions that typically arise during spill response and clean-up. For example,

- By predicting change in an oil's viscosity (resistance to flow) over time, ADIOS2 offers an answer to the question: Can the oil still be dispersed with chemical dispersants?
- By predicting the rate of increase in an oil's water content over time, ADIOS2 offers an answer to questions like: If 1,000 gallons of crude oil has spilled, will more than 1,000 gallons of oil-and-water mixture need to be cleaned up and disposed of? How much more?

ADIOS2 includes new models to estimate the effects of common clean-up techniques such as chemically dispersing, skimming, or burning the oil, and it accounts for environmental processes not included in the previous version, such as sedimentation. It also includes an expanded online help and electronic manual.

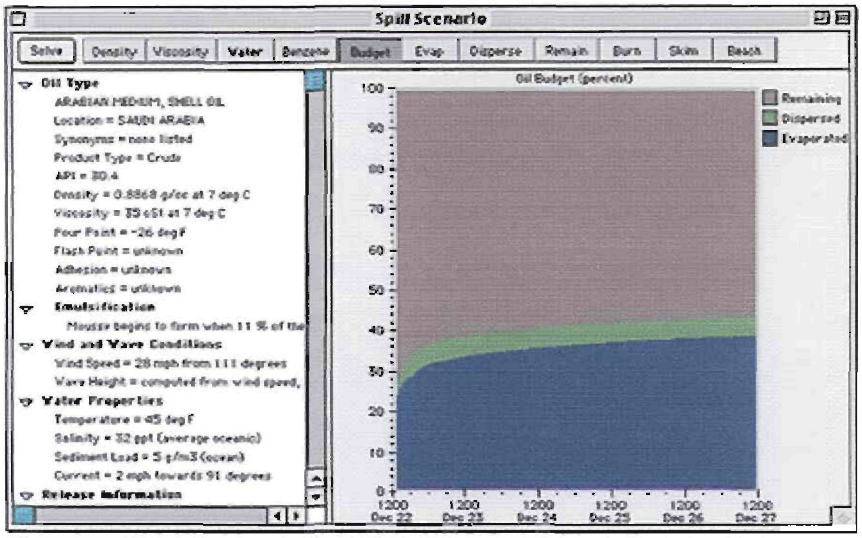
Oil Library

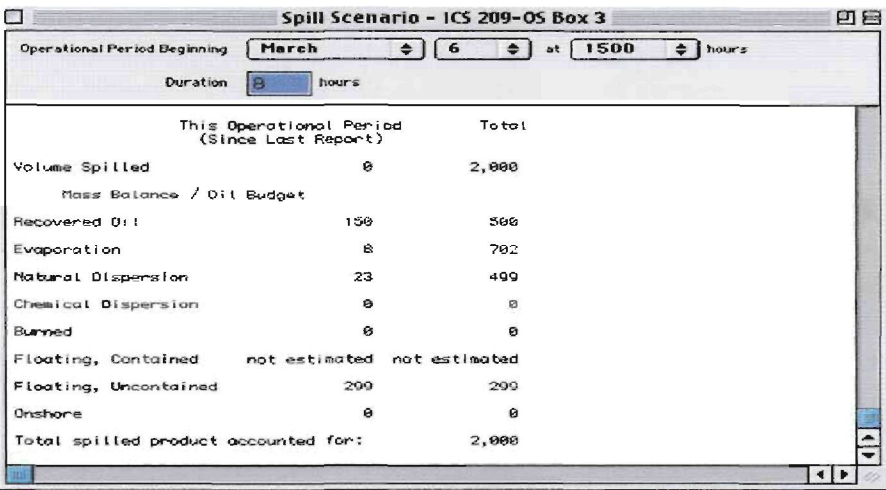
The ADIOS2 database includes estimates of the physical properties of oils and products. ADIOS uses this information to predict changes in an oil's properties once it has spilled. The ADIOS2 oil library was compiled from a number of different sources, including Environment Canada, the U.S. Department of Energy, the International Oil Companies' European Organisation for Environmental and Health Protections (CONCAWE), and industry. Information about the location, density, viscosity, flash point, pour point, hydrocarbon group analysis, and distillation data is included in the database. In addition to using the standard library, you may build or modify a custom library of specific oils.

ADIOS uses mathematical equations and information from the database to predict changes over time in the density, viscosity, and water content of an oil or product, the rates at which it evaporates from the sea surface and disperses into the water, and the rate at which an oil-in-water emulsion may form. It was designed to make use of as little information as possible, and to use information that can quickly be estimated or obtained in the field, such as wind speed(s), wave heights, water temperature, and salinity or density, the type and amount of oil or product spilled, and the rate and duration of the spill.

Using ADIOS2

ADIOS2 asks for information on the spill itself, environmental conditions, and the planned clean-up strategy. You have several choices for entering and calculating the oil leak rate from the source of the spill. Extensive on-line help is available for all of the input requirements, explaining the use of the data, allowable values, where data may be obtained, and reasonable default values. The help is progressive, providing information on specific input requirements, as well as a basic background on standard spill clean-up technology and terminology. Technical documentation for the algorithms are available for spill researchers as part of the help. The model displays the predicted property changes and estimated oil budget for a given time as a graph, table, or text summary. Output can be formatted to fit the Incident Command System Standard Form 209.





Model Parameters

The programme provides you with a best-guess answer and also calculates possible ranges in the values of estimated spill properties. ADIOS2 contains several new extensions from earlier versions. Many of the weathering algorithms have been improved and new processes such as sedimentation and airborne benzene concentration estimation have been added. The oil properties and processes displayed by the programme are listed below.

Oil Properties	**Processes**
· density	· dispersion
· viscosity	· evaporation
· water fraction	· emulsification
· benzene hazard	· spreading
	· beaching
	·in-situ burning
	· leak rate
	· skimming
	· smoke plume

Note:

ADIOS does not run on Macintosh computers with Intel microprocessors. The ADIOS team is researching this problem and hopes to identify a solution.

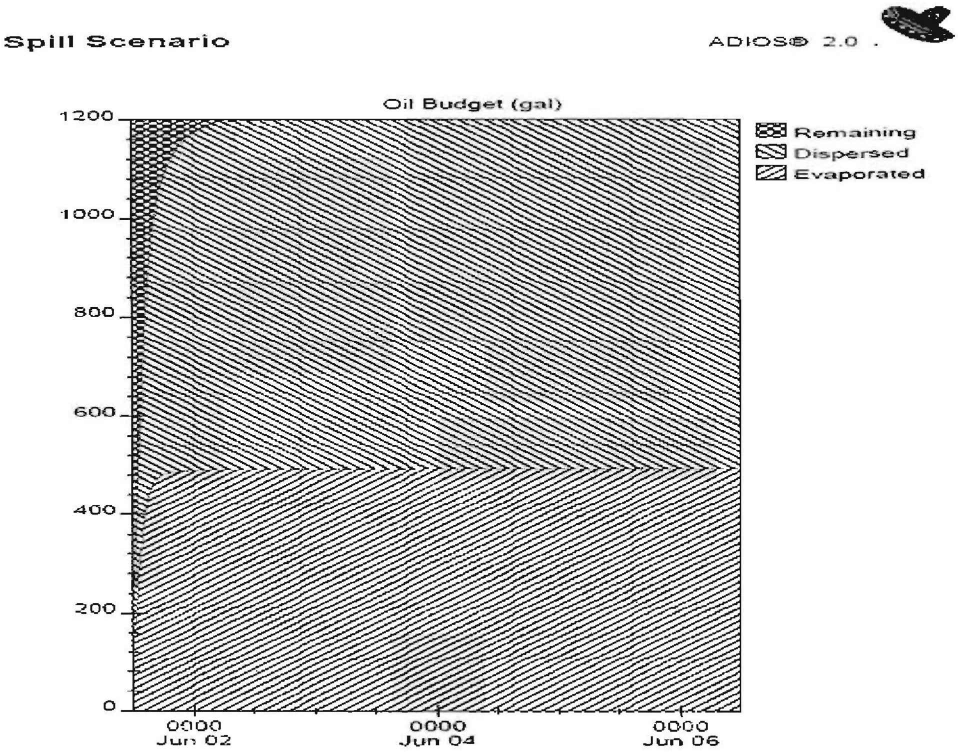
ADIOS2 will make predictions for a maximum of five days. For periods longer than this, other processes, such as bio-degradation and photo-oxidation, may be important. The programme does not model these processes.

For additional information or to obtain ADIOS2:http://response.restoration.noaa.gov/adiosorr.adios@noaa.gov (206) 526-6317

U.S. Department of Commerce • National Oceanic and Atmospheric Administration

November 2006

APPENDIX D1: SIMULATION OUTPUT CHARTS



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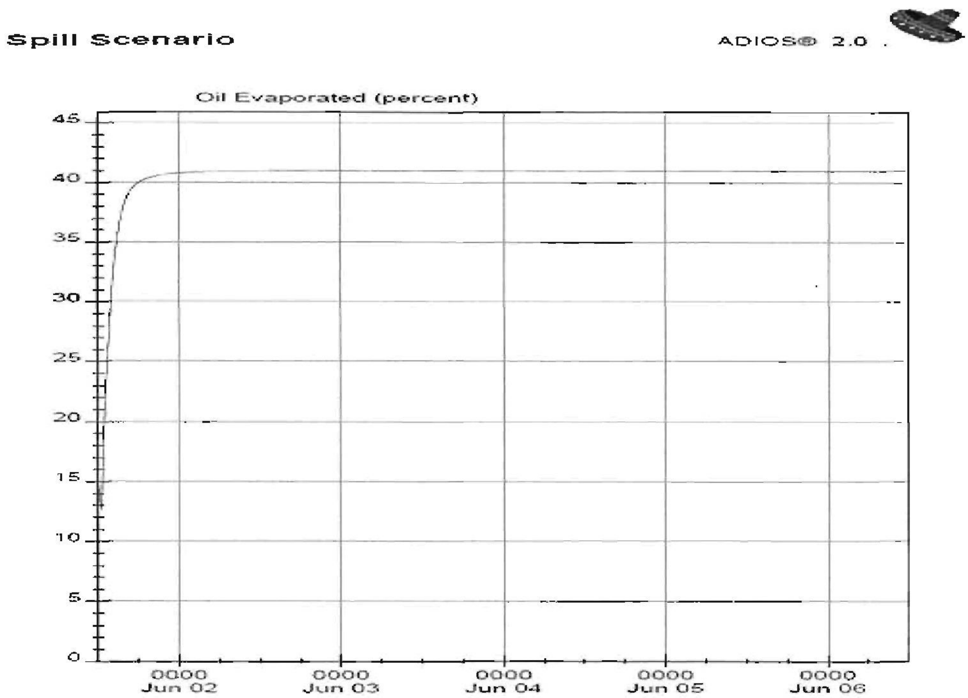

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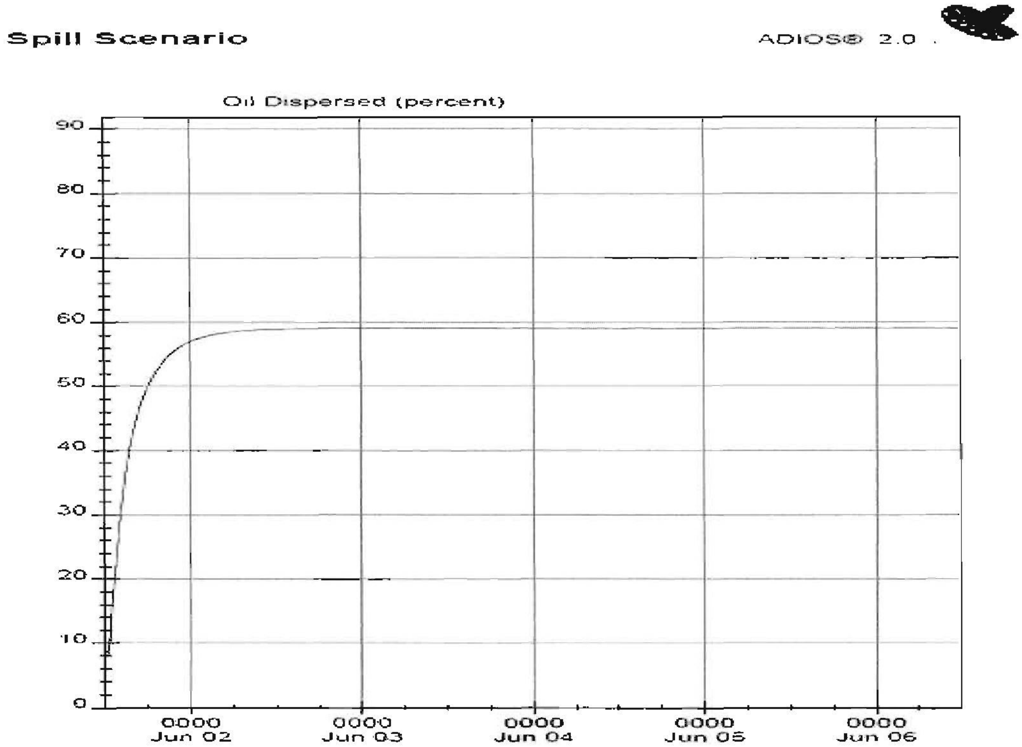
Spill Scenario
ADIOS® 2.0
Oil Dispersed (percent)
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80
70
60
50
40
30
20
10
0
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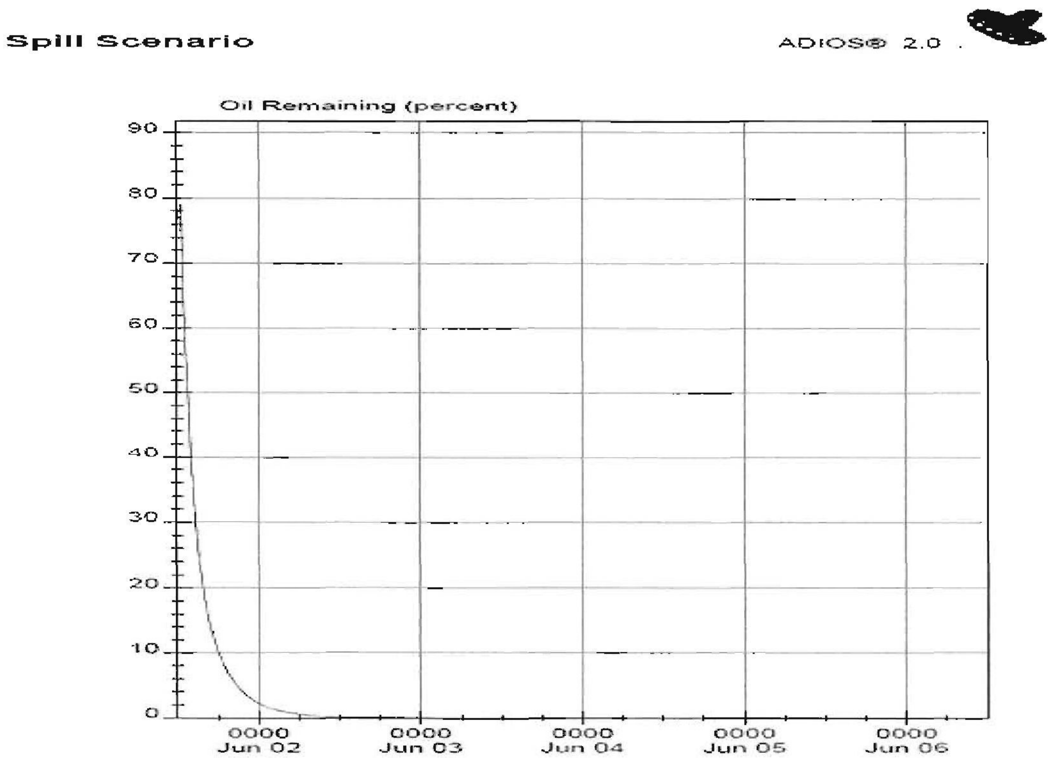
0000 Jun 04
0000 Jun 05
0000 Jun 06

D1-C


Spill Scenario
ADIOS® 2.0
Oil Remaining (percent)
90
80
70
60
50
40
30
20
10
0
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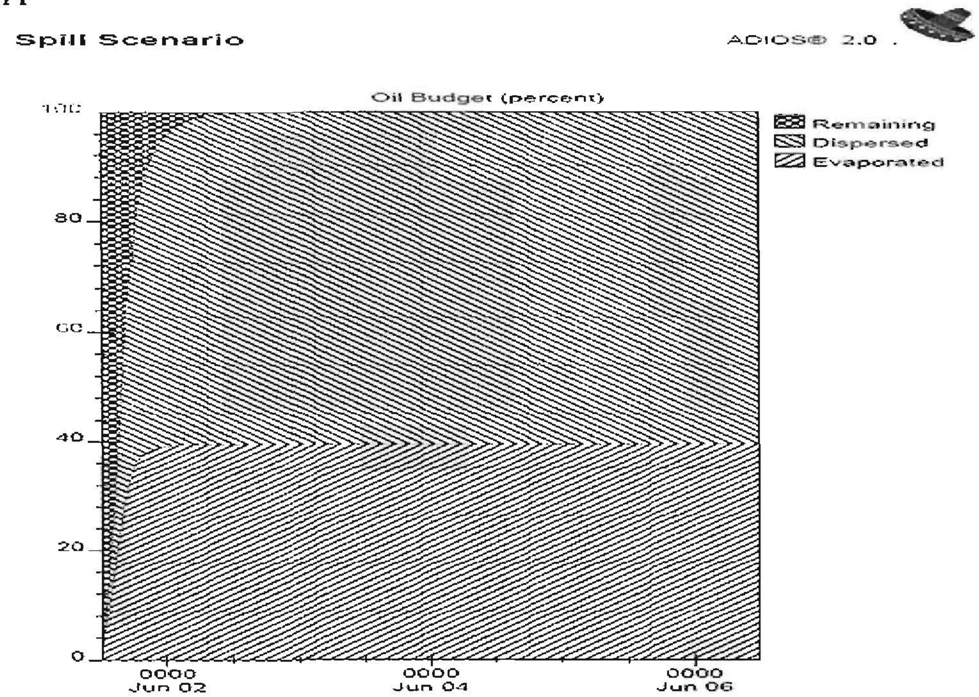
0000 Jun 03
0000 Jun 04
0000 Jun 05
0000 Jun 06

D1-D

Appendix D2



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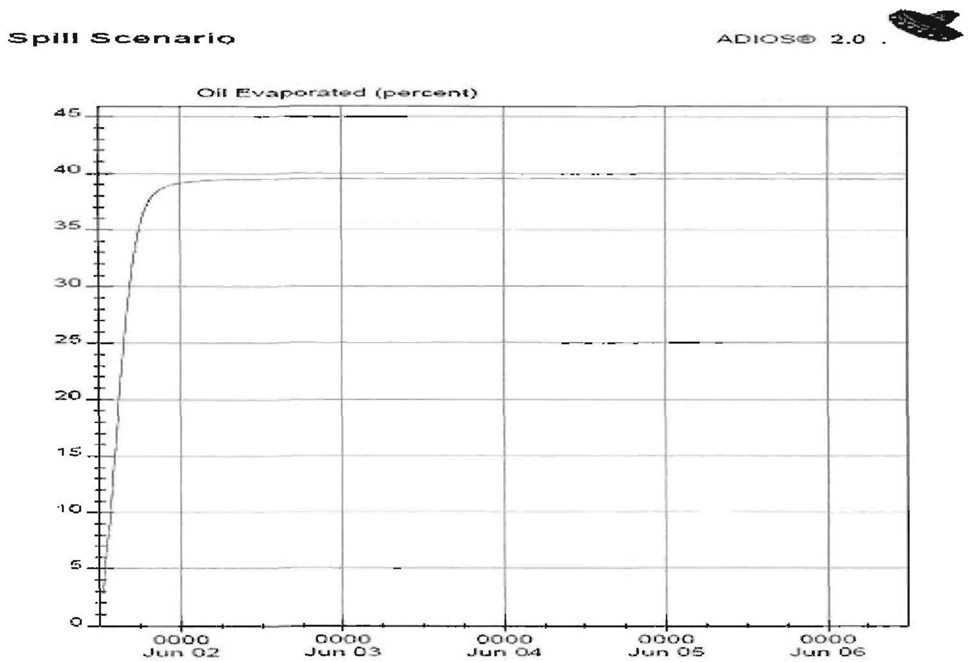
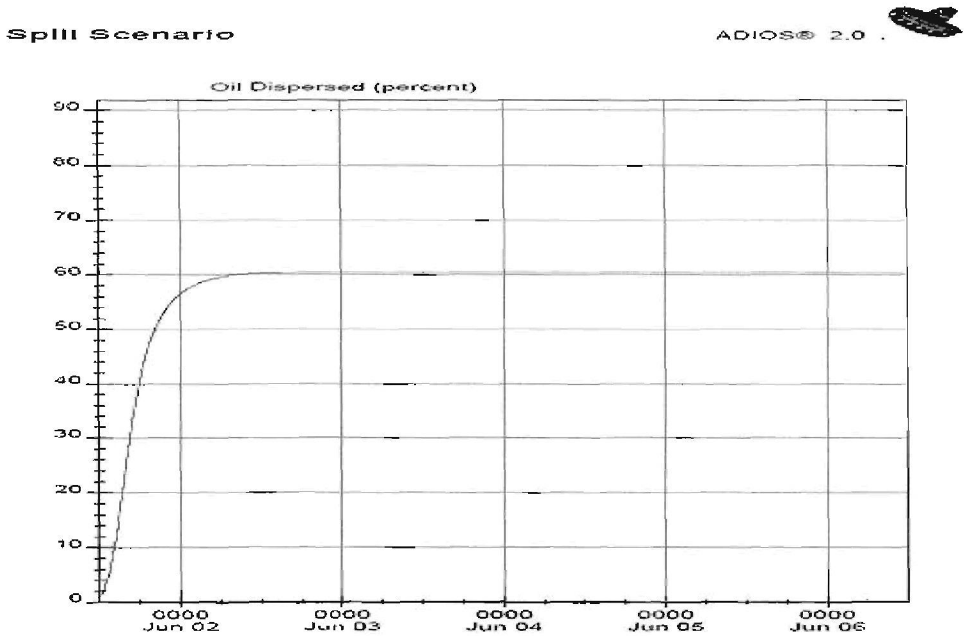
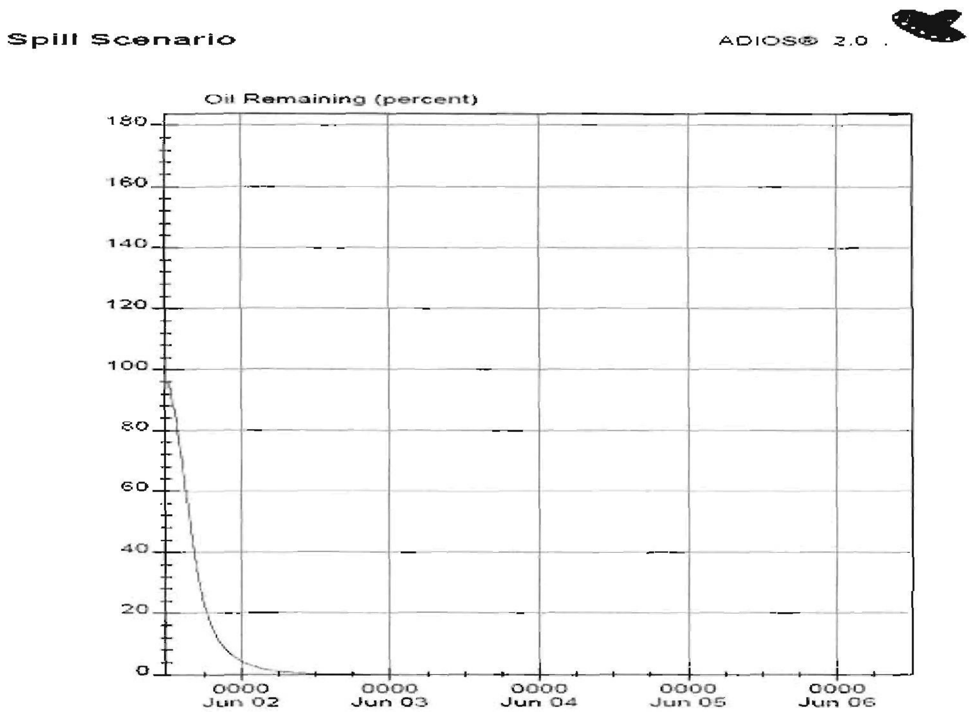


D2-B

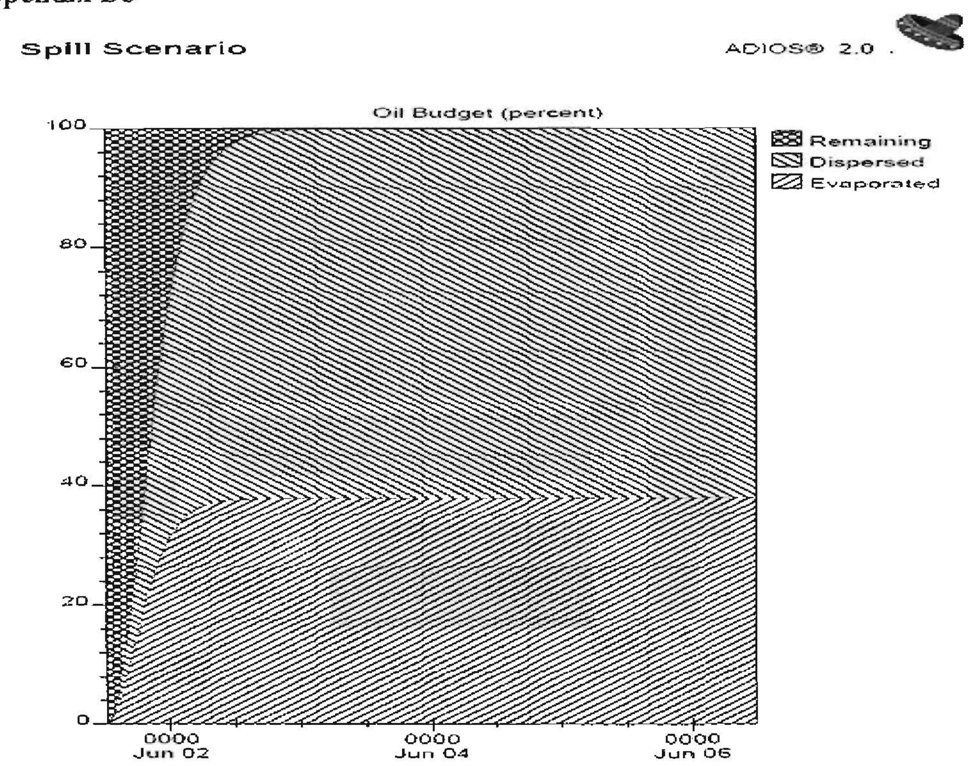

Spill Scenario
ADIOS® 2.0
Oil Dispersed (percent)
90
80
70
60
50
40
30
20
10
0
0000 Jun 02
0000 Jun 03
0000 Jun 04
0000 Jun 05
0000 Jun 06

D2 C

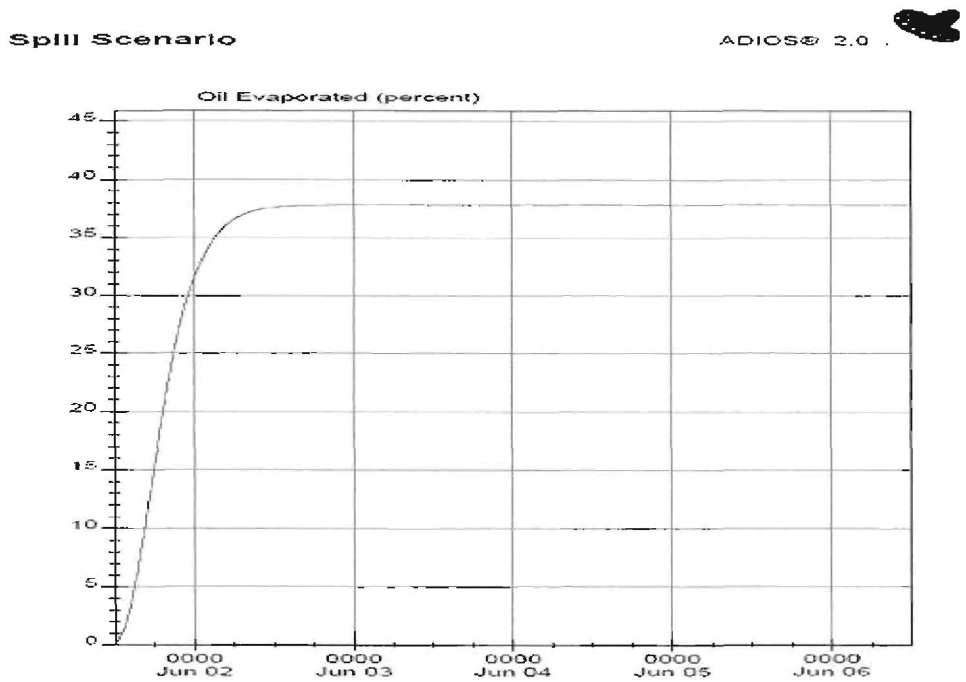

Spill Scenario
ADIOS® 2.0
Oil Remaining (percent)
180
160
140
120
100
80
60
40
20
0
0000 Jun 02
0000 Jun 03
0000 Jun 04
0000 Jun 05
0000 Jun 06

D2 D

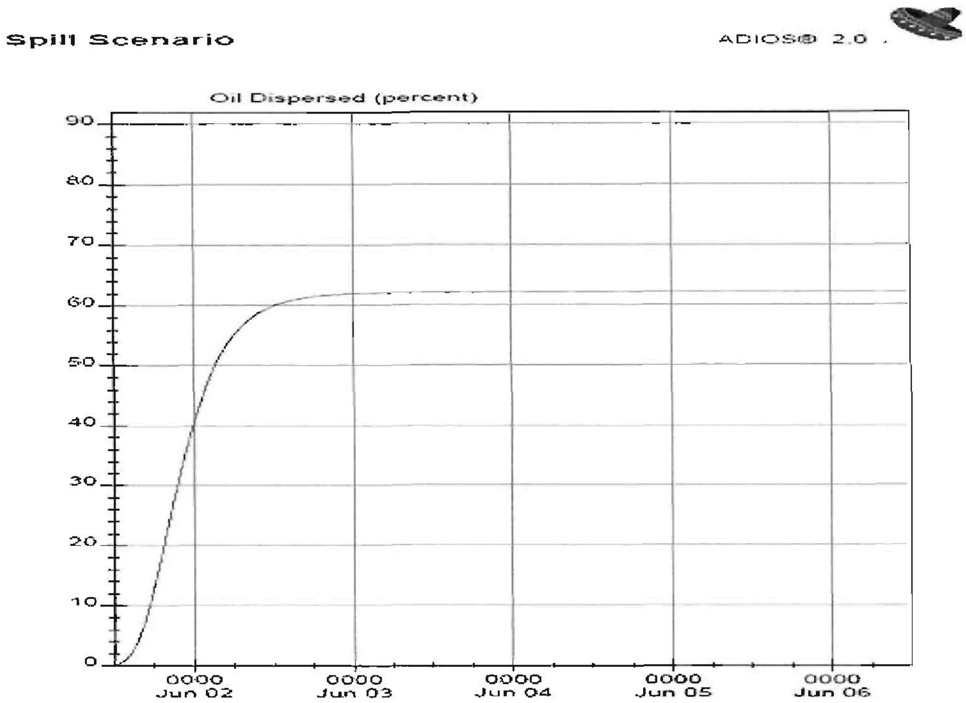
Appendix D3



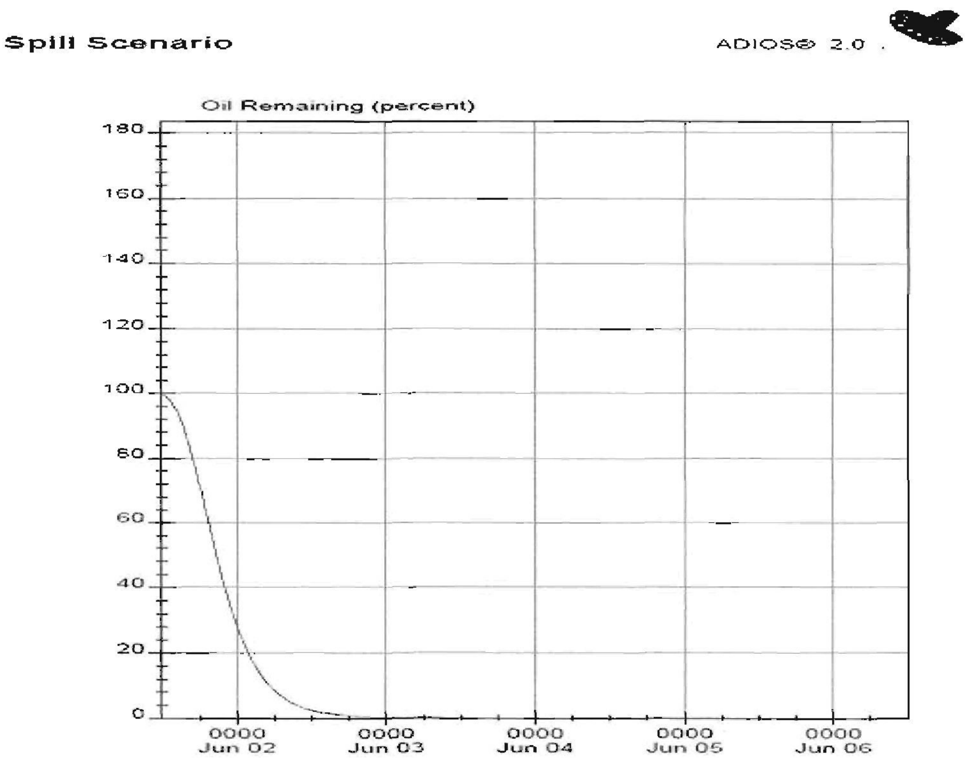
D3 A



D3 B

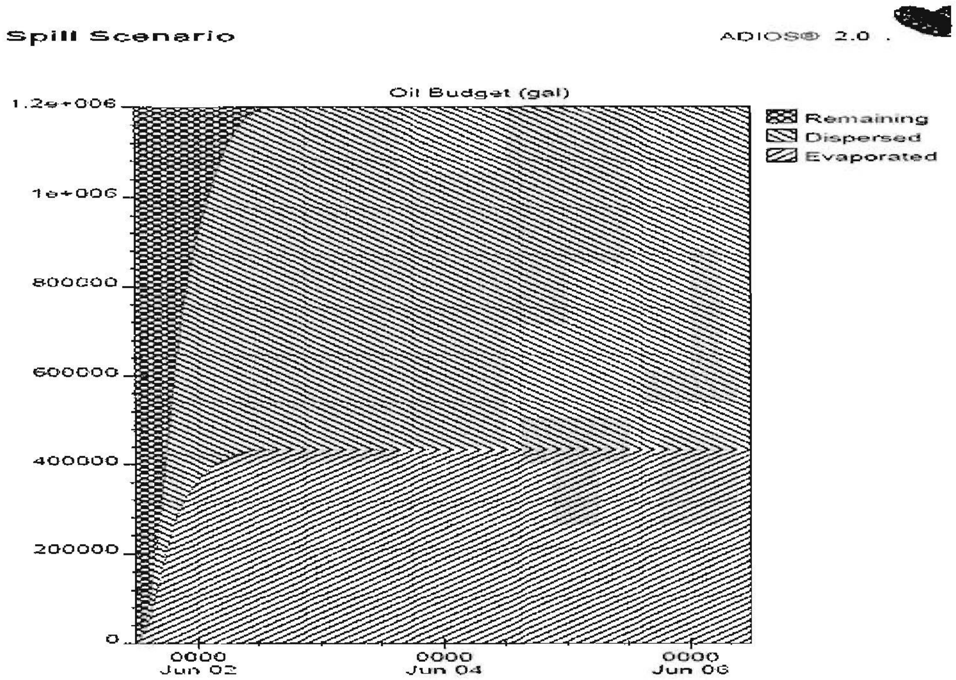

Spill Scenario
ADIOS® 2.0
Oil Dispersed (percent)
90
80
70
60
50
40
30
20
10
0
0000 Jun 02
0000 Jun 03
0000 Jun 04
0000 Jun 05
0000 Jun 06

D3 C

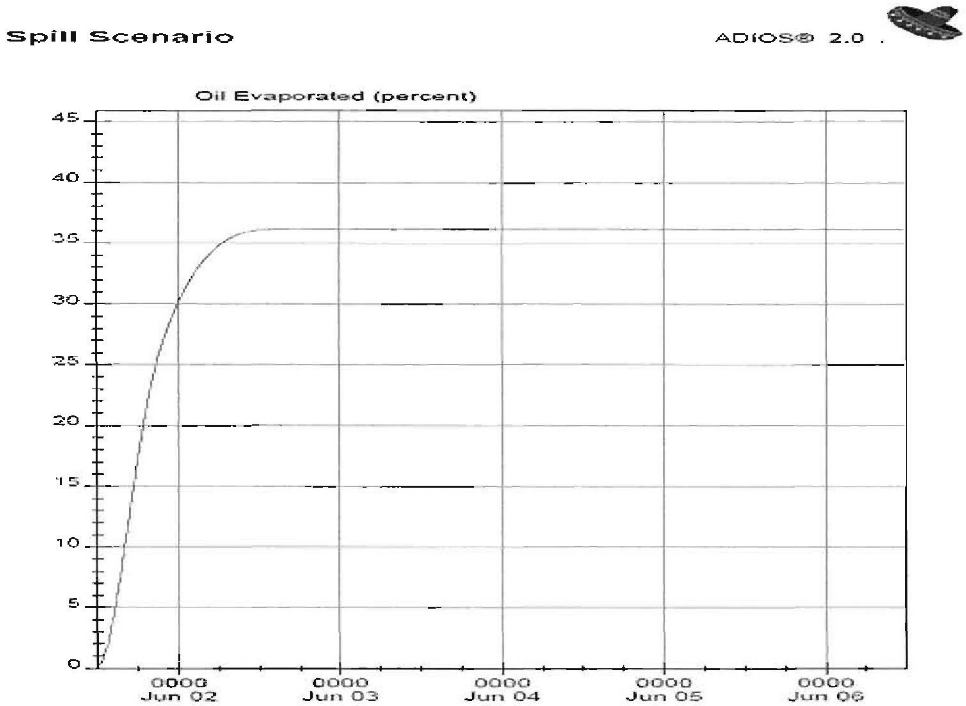

Spill Scenario
ADIOS® 2.0
Oil Remaining (percent)
180
160
140
120
100
80
60
40
20
0
0000 Jun 02
0000 Jun 03
0000 Jun 04
0000 Jun 05
0000 Jun 06

D3 D

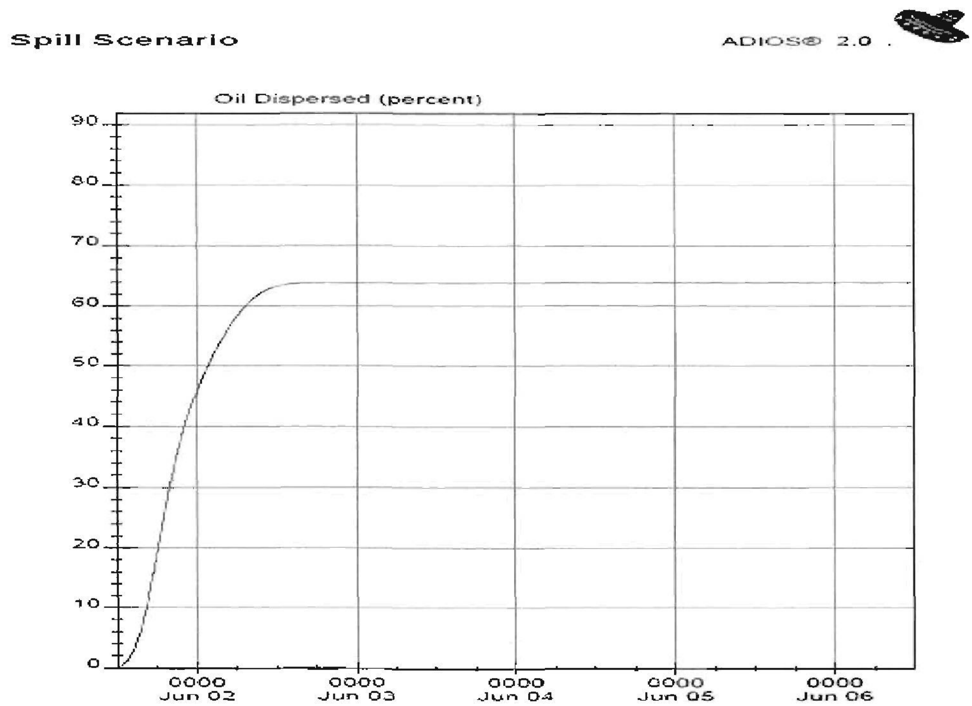
Appendix D4



D4 A

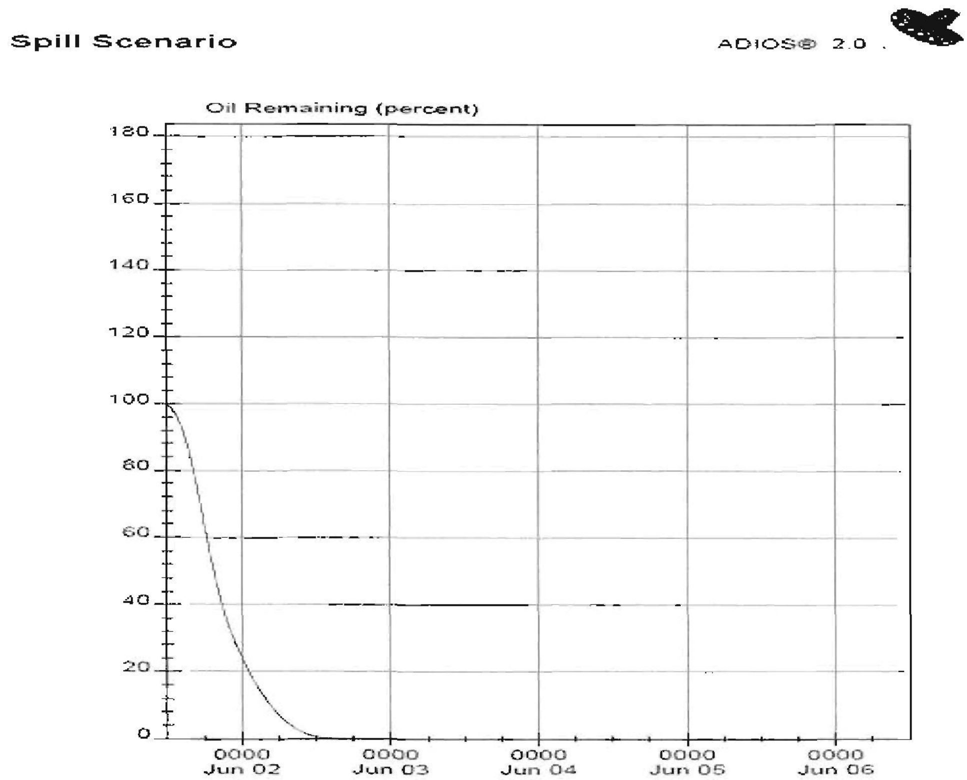


D4 B



Spill Scenario
ADIOS® 2.0
Oil Dispersed (percent)
90
80
70
60
50
40
30
20
10
0
0000 Jun 02
0000 Jun 03
0000 Jun 04
0000 Jun 05
0000 Jun 06

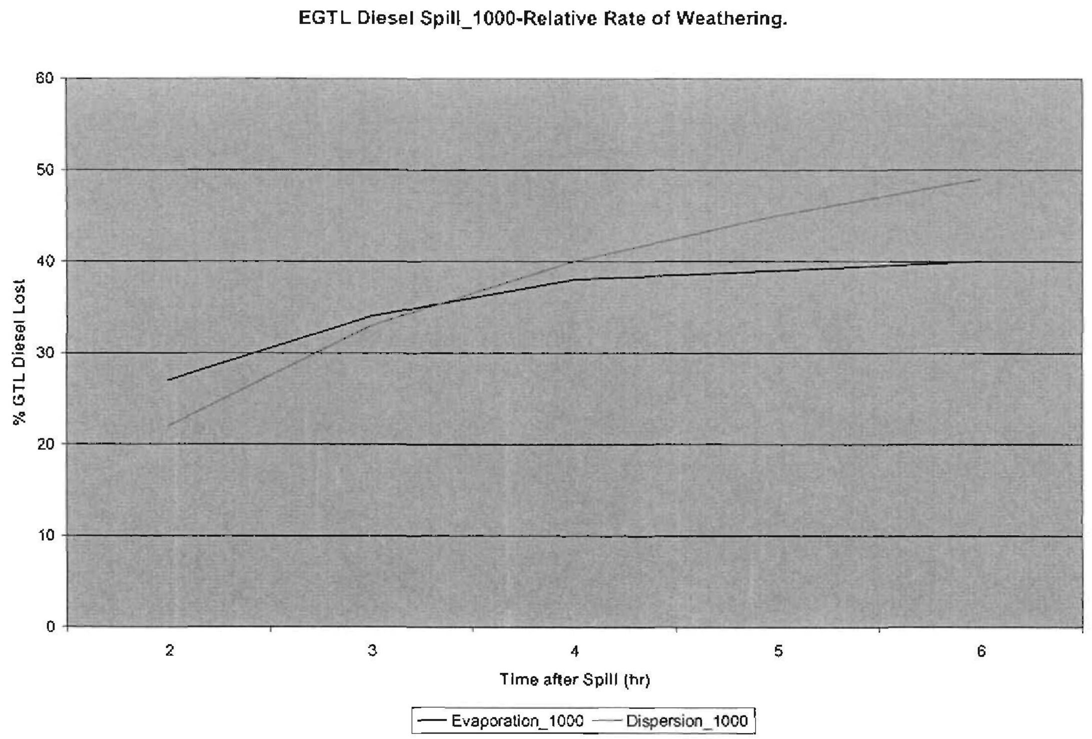
D4 C



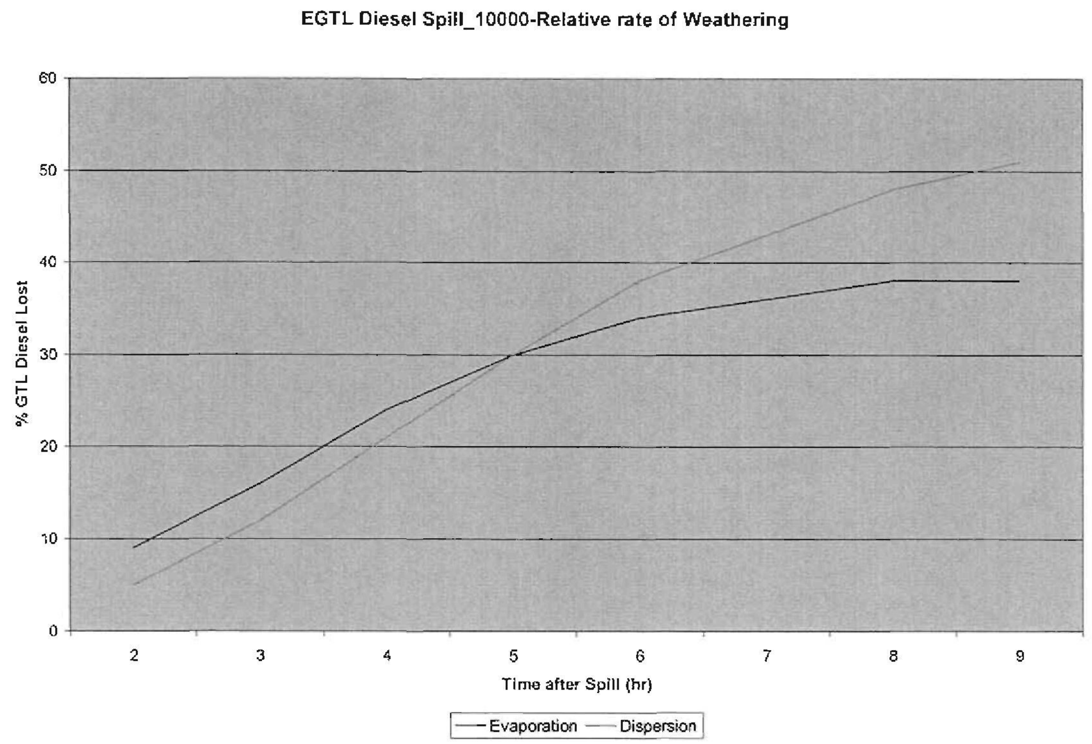
Spill Scenario
ADIOS® 2.0
Oil Remaining (percent)
180
160
140
120
100
80
60
40
20
0
0000 Jun 02
0000 Jun 03
0000 Jun 04
0000 Jun 05
0000 Jun 06

D4 D

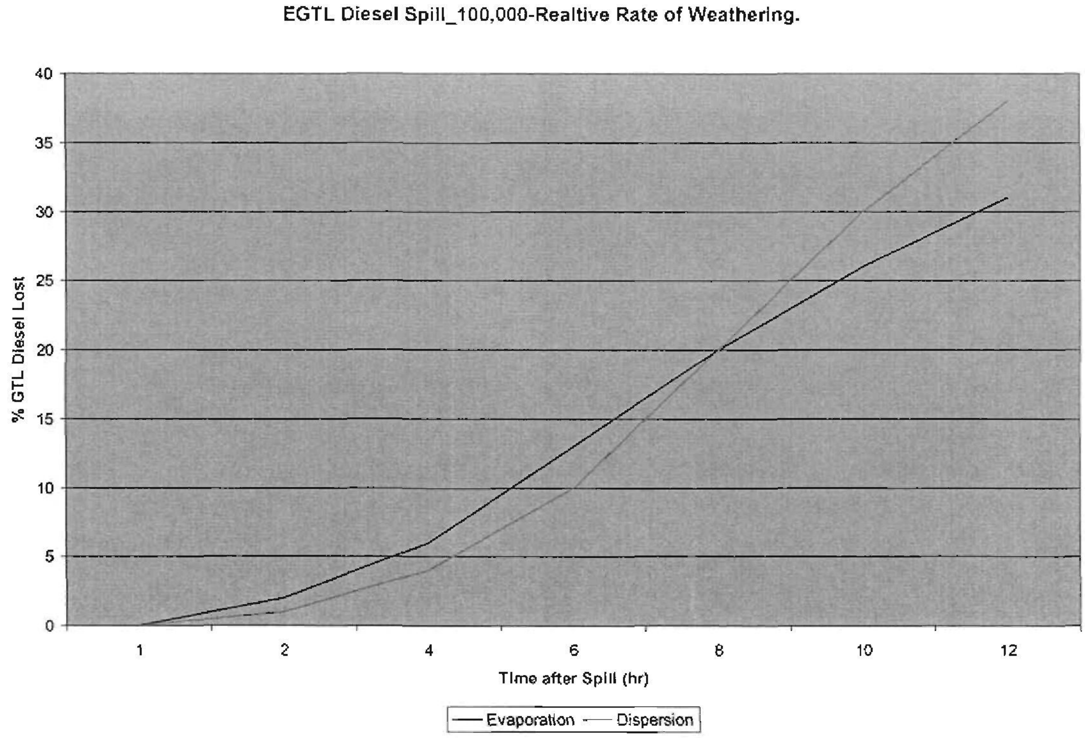
APPENDIX E



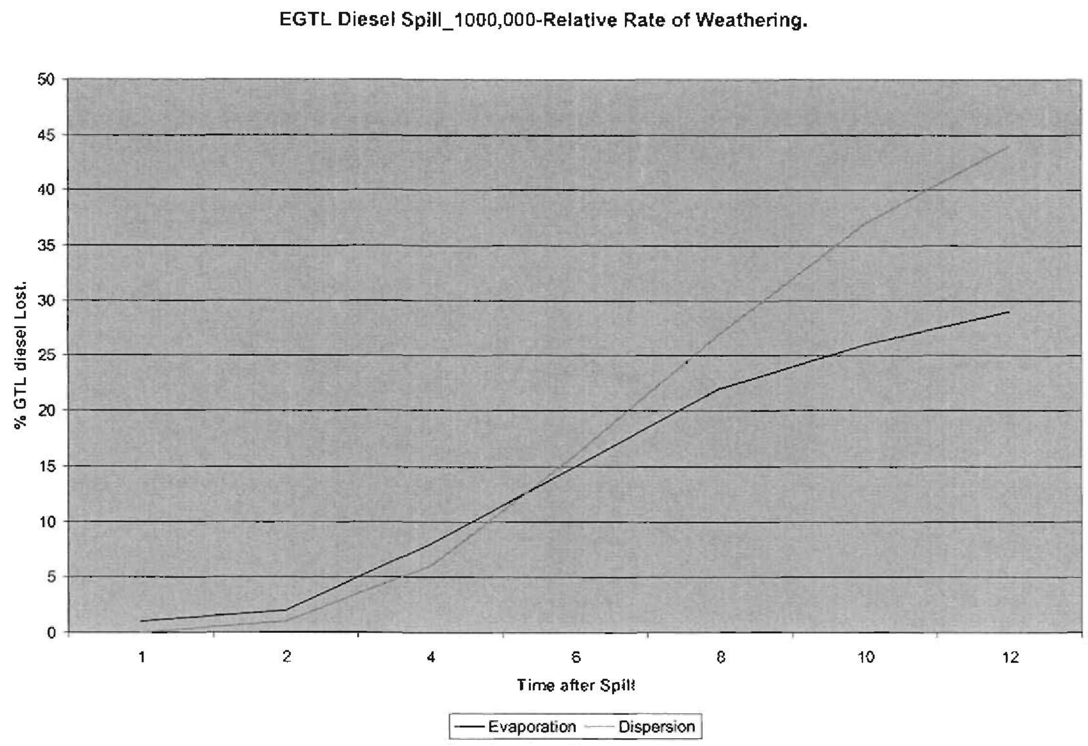
E1



E2


EGTL Diesel Spill_100,000-Realtive Rate of Weathering.
% GTL Diesel Lost
Time after Spill (hr)
Evaporation
Dispersion

E3


EGTL Diesel Spill_1000,000-Relative Rate of Weathering.
% GTL diesel Lost.
Time after Spill
Evaporation
Dispersion

E4

APPENDIX F

CORRELATION ANALYSIS FOR EXCRAVOS GTL DIESEL SPILL : SCENARIO_3 (100,000 gallons).

LOSS ESTIMATION RELATIONSHIP

X = Time after spill

Y = % Loss of GTL Diesel

where $\bar{X} = \Sigma X / n$

$\bar{Y} = \Sigma Y / n$

Graphical Method Plot shows the Curve is Linear; Curve-of-Best-fit so therefore $y = a + bX$ is the Model Character where $n = 6$,

X	Y	X·Y	X^2	Y^2	
2	3	6	4	9	
4	10	40	16	100	
6	23	138	36	529	
8	40	320	64	1600	
10	56	560	100	3136	
12	69	828	144	4761	
42	201	1892	364	10135	Σ

$$b = \frac{\Sigma xy - n\bar{x}\bar{y}}{\Sigma x^2 - n\bar{x}^2}, \quad a = \bar{y} - b\bar{x}$$

$$\bar{X} = \frac{2+4+6+8+10+12}{6} = 7$$

$$\bar{Y} = \frac{3+10+23+40+56+69}{6} = 33.5\%$$

$$b = \frac{1892-(6)(7)(33.5)}{364-(6)(7)^2} = \frac{485}{70} = 6.9285714 \simeq \underline{6.929}$$

$$\therefore a = 33.5 - (6.9285714)(7) = -14.384616 \simeq \underline{-14.999}$$

$\therefore$ The Equation Model for Scenario 3;

$$Y_c = -14.999 + 6.929 X_c$$

COEFFICIENT OF DETERMINATION (R^2)

$$R^2 = \frac{(\Sigma xy - n\bar{x}\bar{y})^2}{(\Sigma x^2 - \bar{x}\Sigma x)\cdot(\Sigma y^2 - \bar{y}\Sigma y)} = \frac{\left[1892-(6)(7)(33.5)\right]^2}{\left[364-(7)(42)\right]\cdot\left[10135-(33.5)(201)\right]} = 0.9879044$$

$$\simeq 0.988$$

COEFFICIENT OF CORRELATION (R)

$$R = \sqrt{\frac{(\Sigma xy - n\bar{x}\bar{y})^2}{(\Sigma x^2 - \bar{x}\Sigma x)\cdot(\Sigma y^2 - \bar{y}\Sigma y)}} = \sqrt{0.9879044} = \underline{0.994}$$

APPENDIX G

Urgent_Research needs_TAP II and GNOME Inbox

Uzodimma Anistus Chukwu | Sir/Madam, I am a research Student (student #: 20498640) of North-West Univ... | Apr 1

CJ Beegle-Krause to me, OR R.G NOME | show details Apr 24 | Reply | Reply to all | Forward | Print | Add CJ to Contacts list | Delete this message | Report phishing | Show original | Message text garbled?

Dear Chukwu usodimma Anistus,

Thank you for your interest in GNOME. Unfortunately we do not work outside the USA except at the request of the U.S. State Department.

You should check our ADIOS2 software (http://response.restoration.noaa.gov/adios) regarding the high evaporation of diesel and naptha fuels. Diesel does not generally create a persistent slick, and beach contact generally results in staining rather than heavy oiling. Though diesel is less persistent than most oils, it is also more toxic in the water column.

You can create your own GNOME Diagnostic Mode .sav file for your area of interest. You'll need a map in BNA format, circulation model for the river entrance, estimate of horizontal mixing and wind information. The GNOME Web Site has example files for each of these type of input data.

Let us know if you have any further questions.

Best regards,
CJ

--
CJ Beegle-Krause, Ph.D.
NOAA/NOS/ORR/Hazmat
7600 Sand Point Way NE
Seattle, WA 98115
voice: (206) 526-6961
fax: (206) 526-6329

APPENDIX H

Validation and Verification Request on ADIOS Simulation !

from CJ Beegle-Krause <Cj.Beegle-Krause@noaa.gov> hide details Jun 4

to Uzodimma Anistus Chukwu <uzoanis@gmail.com>

date Jun 4, 2007 8:06 PM

subject Re: Validation and Verification Request on ADIOS Simulation !

mailed-by noaa.gov

Hello Chukwu usodimma Anistus,

You are correct that small diesel spills evaporate very quickly I've attached out one-pager on diesel spills of less than 5,000 gallons. Below is our standard diesel spill descriptor.

Light refined products, such as diesel (or Fuel Oil No 2), typically have very high evaporation rates and do not tend to create persistent slicks. However, the terminology for refined products is not standardised, and, sometimes, heavier intermediate fuel oils are referred to as 'marine diesel'. These heavier products are much less volatile than normal Fuel Oil no 2 and can form a more persistent slick.

When spilled, the diesel spreads quickly into thin films often forming patches of rainbow and silver sheens. If the sheens reach the shoreline in a few hours, a slight staining, or greasy film-like bathtub ring is common. These oils usually do not form a stable emulsion and, as a result, do not form a heavy or sticky residual to clean up.

Note that lighter refined products do have a relatively high concentration of light aromatic compounds and tend to be more soluble and more toxic than heavier oils. These oils do not generally present an involved clean-up problem. However, they can result in an initial toxic shock to biota and can persist as a biological threat in low energy marine environments.

Since the diesel evaporates so quickly, there may be no recoverable oil remaining in the environment by the time response equipment arrives on-scene Now, if you have a potential for much larger spills (e.g. millions of gallons), that is a different matter. Let me know if you have any further questions.

Best regards,
CJ
- Show quoted text -

small diesel spills.pdf
341K View as HTML Download

xcxccxcxcxcxcxcxcxcxcxcxcxcxcxcxcxcxcxcxcxcxcxcxcxcxcxcxcxcxcxcxcxcxcxcxcxcx

from CJ Beegle-Krause <Cj.Beegle-Krause@noaa.gov> hide details Jun 26 (5 days ago)
to Uzodimma Anistus Chukwu <uzoanis@gmail.com>
date Jun 26, 2007 11:06 PM
subject Re: Validation and Verification Request on ADIOS Simulation!
mailed-by noaa.gov

Hello again! My apologies for the delay in responding, as I was preparing for a large drill and then on travel. Response and clean up options vary depending on the properties of the oil related to fate and weathering (e.g. how quickly it will evaporate), the type of spill (a few gallons to millions of gallons) and the habitat affected by the spill. Have there been any response equipment tests with FT-diesel? For example, do conventional skimmers work? Does it evaporate quickly enough that the spill will disappear in a matter of hours? Do you expect a spill to move into a sensitive habitat such as marsh or mangroves, or into more commercial areas such as marinas, or into easier areas to clean such as sand beaches? This is not an easy questions, particularly if there is no response history with this product.

- Show quoted text

APPENDIX I

GC-LABORATORY RGA-REPORT (D)

COMPOSITION OF SYNGAS PRODUCED @ ATR PLANT, SASOL ONE SITE. SASOLBURG

DATE	7/1/2006	7/4/2006	7/5/2006	7/17/2006	7/18/2006	7/19/2006	7/20/2006	7/26/2006	7/27/2006	7/28/2006	7/29/2006	7/30/2006	AVERAGE
COMPONENTS	MOL %	MOL %	MOL %	MOL %	MOL %	MOL %	MOL %	MOL %	MOL %	MOL %	MOL %	MOL %	
hydrogen	64.38	64.07	64.66	64.52	64.68	64.64	64.48	64.91	65.17	64.6	64.69	64.9	64.64
methane	1.97	1.82	1.76	1.71	1.67	1.6	1.59	1.64	1.58	1.56	1.56	1.56	1.67
carbon monoxide	28.13	28.37	27.97	28.22	28.17	28.08	28.18	28.02	26.91	27.48	27.42	27.1	27.84
nitrogen	0.77	0.78	0.74	0.74	0.74	0.75	0.73	0.72	0.76	0.73	0.73	0.79	0.75
ethylene	0	0	0	0	0	0	0	0	0	0	0	0	0.00
ethane	0	0	0	0	0	0	0	0	0	0	0	0	0.00
oxygen/argon	0.25	0.27	0.18	1.9	0.2	0.19	0.22	0.2	0.18	0.19	0.2	0.23	0.35
propylene	0	0	0	0	0	0	0	0	0	0	0	0	0.00
carbon dioxide	4.72	4.69	4.7	4.62	4.55	4.74	4.79	4.51	5.4	5.44	5.41	5.42	4.92
propane	0	0	0	0	0	0	0	0	0	0	0	0	0.00
1-butane	0	0	0	0	0	0	0	0	0	0	0	0	0.00
n-butane	0	0	0	0	0	0	0	0	0	0	0	0	0.00
1-pentane	0	0	0	0	0	0	0	0	0	0	0	0	0.00
n-pentane	0	0	0	0	0	0	0	0	0	0	0	0	0.00
C6 +	0	0	0	0	0	0	0	0	0	0	0	0	0.00
H2/CO (TRAIN A)	2.29	2.26	2.31	2.29	2.33	2.3	2.29	2.32	2.42	2.35	2.36	*2.38	2.32
H2/CO (TRAIN B)	2.29	2.27	2.3	2.29	2.3	2.34	2.26	2.25	2.27	2.31	2.27	*2.34	2.29

APPENDIX J

Mail from Operations Manager of EGTL Project.

Subject:	RE: Hello & see my Dissertation!
Date:	Wed, 29 Aug 2007 17:10:59 +0100
From:	"Vorster, Vossie" <VORJ@chevron.com> View Contact Details Add Mobile Alert
To:	uzo_anis@yahoo.com
CC:	"Peens, Christiaan A (CPEE) SASOL [Contractor]" <cpee@chevron.com>

Anistus
This is a great peace of work. Hope you will gain a good score on this. I read through the introduction, items 5.2 to 5.4 and am impressed with the research and your advice. We must make time to discuss some of your proposals, as I wondered whether everything as recommended will apply to the EGTL plant and would like to understand a bit better. I will make time to read more maybe then I will understand better.

Well done
Vossie

From: Peens, Christiaan A (CPEE) SASOL [Contractor]
Sent: 29 Aug 2007 12:28
To: Storm, Matthys (MTSJ) SASOL [Sasol]; Vorster, Vossie
Subject: FW: Hello & see my Dissertation!

Thys & Vossie,

Attached is a dissertation of one of our Trainees.

Regards

Chris Peens, Sasol Secondee

Production Manager
Escravos Gas to Liquids
Tel: +27 (0)16 920 2865
Fax: +27 (0)16 920 2865
Cell: +27 (0)84 598 4671

From: Uzo. A. Chukwu [mailto:uzo_anis@yahoo.com]
Sent: 28 August, 2007 12:10
To: Peens, Christiaan A (CPEE) SASOL [Contractor]
Subject: Hello & see my Dissertation!

Hello,

Please,
Find a soft copy of my research thesis for your keeps and relay where necessary.
...focus areas in the dissertation is chapter 4 & 5.

Regards

Anistus

EXCRAVOS GTL PROJECT
REPUPLIC OF SOUTH AFRICA .
Cell:+27-730672205_SA.
Alternate e-mail: **uzoanis@gmail.com**
There is more love when we disagree in love.