

**THE STUDY ON
AN ENVIRONMENTAL ASSESSMENT AND MONITORING
OF ARABIAN GULF
IN THE KINGDOM OF SAUDI ARABIA**

FINAL REPORT

SUMMARY

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January 2001

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JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

**METEOROLOGY AND ENVIRONMENTAL
PROTECTION ADMINISTRATION (MEPA)**

**THE STUDY ON
AN ENVIRONMENTAL ASSESSMENT AND MONITORING
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(as of the beginning of November 2000)

PREFACE

In response to a request from the Government of Kingdom of Saudi Arabia (KSA), the Government of Japan decided to conduct a master plan study on Environmental Assessment and Monitoring of Arabian Gulf and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA selected and dispatched a study team headed by Mr. Yasuhiro Shimazu of Chiyoda-Dames & Moore (CDM) Co., Ltd. to KSA, five times between March 1999 and November 2000. In addition, JICA set up an advisory committee headed by Mr. Masahiro Ota, JICA Development Specialist between March 1999 and November 2000, which examined the study from specialist and technical points of view.

The team held discussions with the officials concerned of the Government of KSA and conducted field surveys at the study area. Upon returning to Japan, the team conducted further studies and prepared this final report.

I hope that this report will contribute to the promotion of this project and to the enhancement of friendly relationship between our two countries.

Finally, I wish to express my sincere appreciation to the officials concerned of the Government of KSA for their close cooperation extended to the Team.

January 2001



Kunihiko Saito
President

Japan International Cooperation Agency

January 2001

Mr. Kunihiko SAITO
President
Japan International cooperation Agency

LETTER OF TRANSMITTAL

Dear Sir,

We are pleased to submit to you the final report entitled "The Study on an Environmental Assessment and Monitoring of Arabian Gulf in the Kingdom of Saudi Arabia". This report has been prepared by the Study Team in accordance with the contracts signed on February 19, 1999, May 20 1999 and May 10, 2000 between the Japan International Cooperation Agency (JICA) and The Study Team organized by Chiyoda-Dames & Moore Co.

The report describes the study results of developing guidelines for the national water quality monitoring program for coastal areas in KSA and developing a specific coastal water quality monitoring plan for the Arabian Gulf area.

The report consists of the Main Report and Summary Report, Supporting Report and Data Book, and Technology Transfer Report in English.

The Main report presents: i) existing states of coastal environment and water quality monitoring, ii) planning policy for the coastal water quality monitoring, iii) the coastal water quality monitoring plan for the Arabian Gulf area. iv) the laboratory plan in the future, and v) the recommendation on the improvement of organization structure for Coastal Zone Management. The summary Report presents these results concisely. The Supporting Report describes technical details concerning the methods of coastal water quality monitoring including field surveys, analysis of sea water quality, laboratory management, and data analysis. The Data Book contains the collected data in KSA and detailed results of monitoring surveys. The Technology Transfer Report describes the various on the job and off the job training activities carried out in the course of the Study, and their evaluations.

We wish to express grateful acknowledgements to the personnel of your Agency, Advisory Committee, Ministry of Foreign Affairs, Environment Agency, and Embassy of Japan in KSA. We also wish to express sincere appreciation to our counterpart, the Meteorology and Environmental Protection Administration (MEPA) of KSA. We hope that the proposed plan and guidelines will contribute to the realization of sustainable development of coastal areas in KSA.

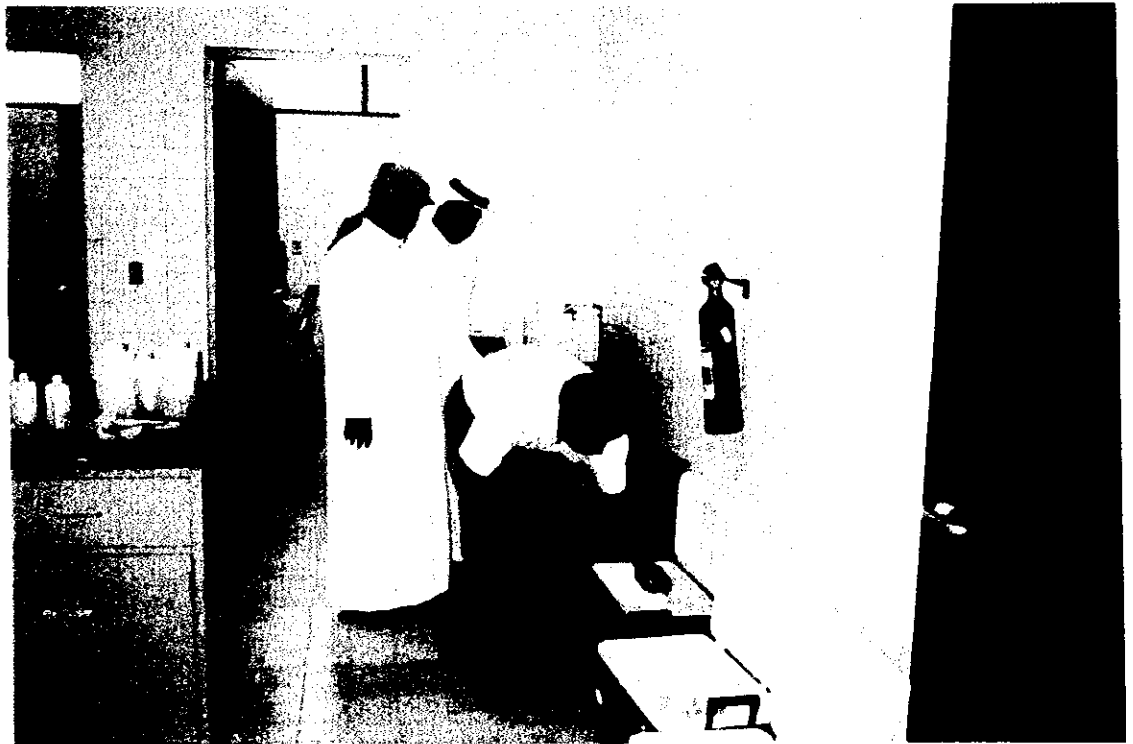
Yours faithfully,

Yasuhiro Shimazu
Team Leader





Monitoring Planning



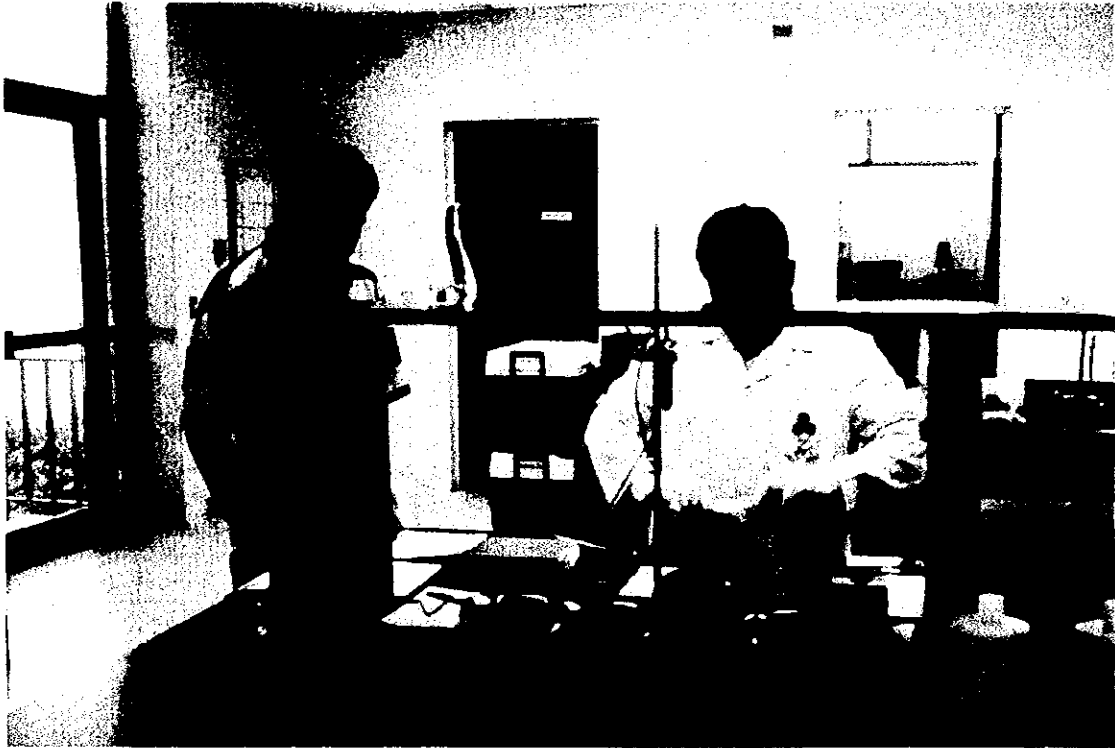
Sampling Bottle Preparation



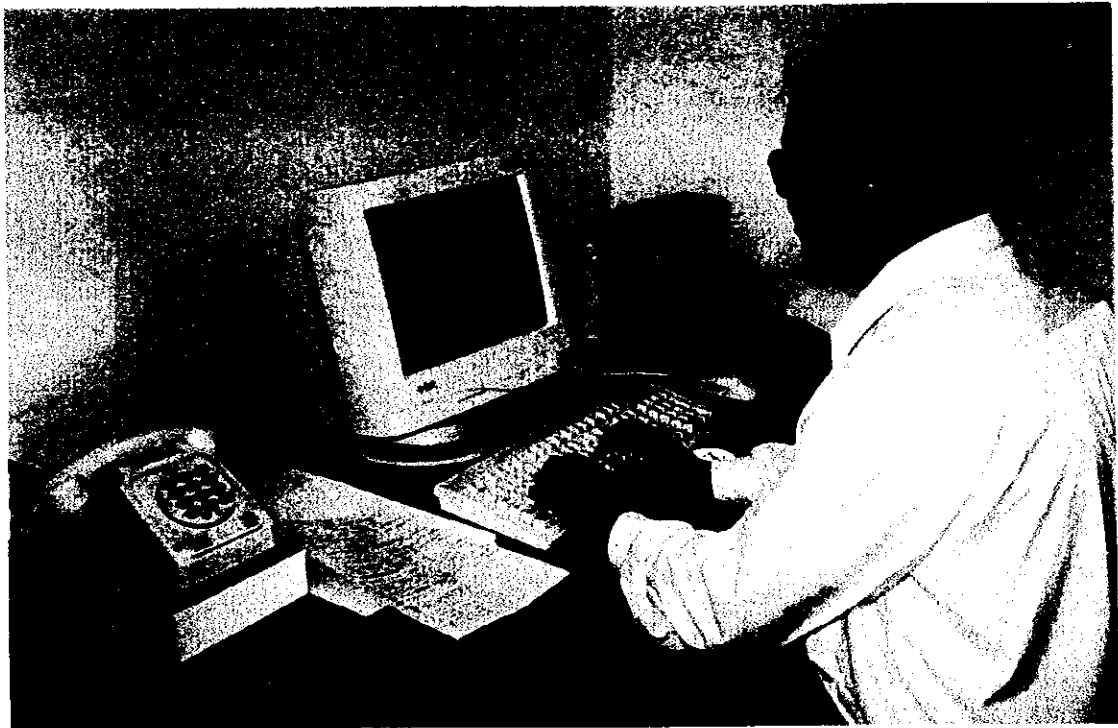
Field Sampling



Field Sampling

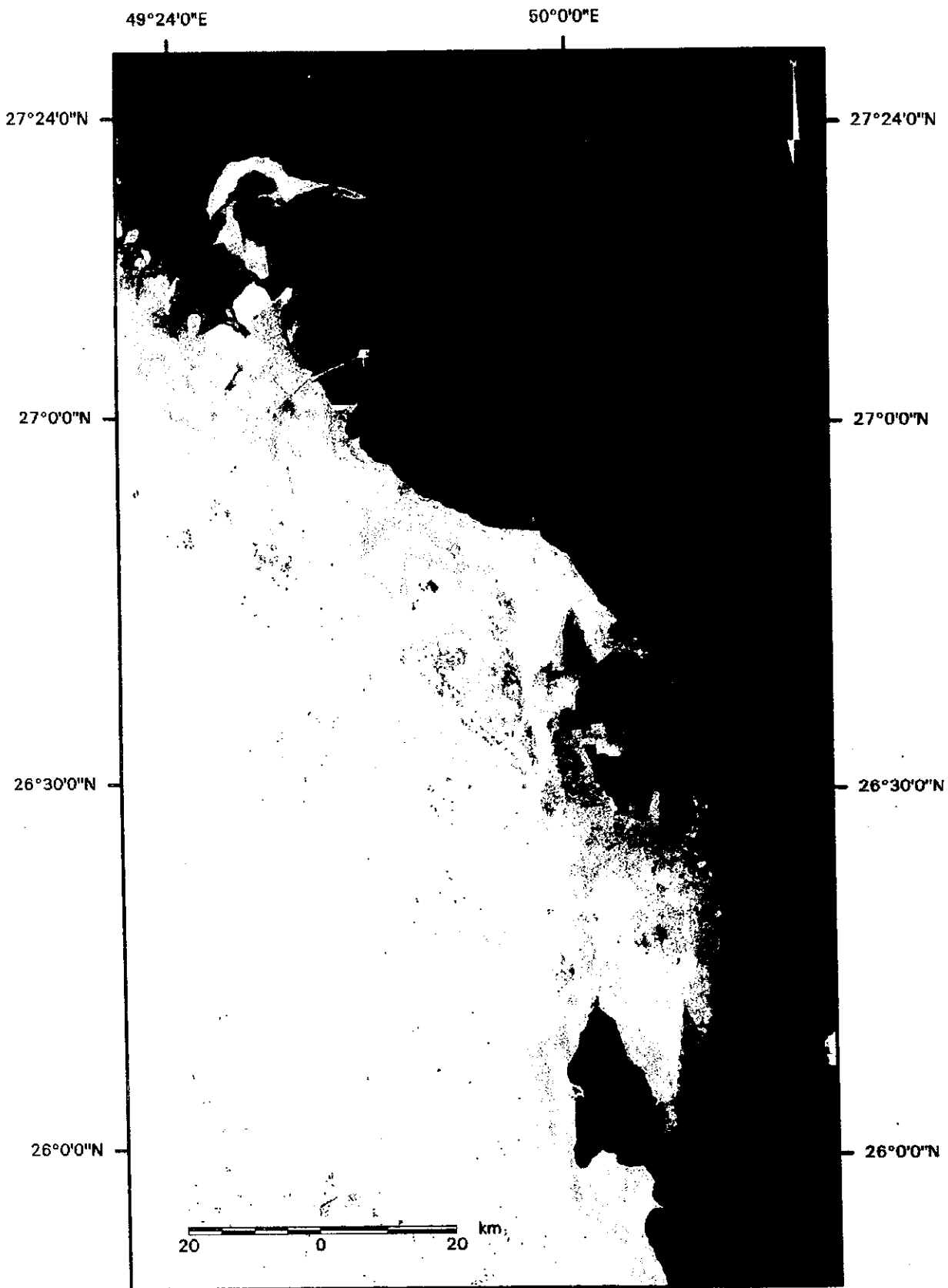


Laboratory Analysis



Data Analysis

Intensive Study Area - Arabian Gulf, Saudi Arabia



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JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)
METEOROLOGY AND ENVIRONMENTAL PROTECTION ADMINISTRATION (MEPA)

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List of Abbreviations /Acronyms

ACOPS	Advisory Committee on Protection of the Sea
ARAMCO	Arabian Oil Company
BOD	Biological Oxygen Demand
COD	Chemical Oxygen Demand
C/P	Counter Part
CZM	Coastal Zone Management
DO	Dissolved Oxygen
E.P.	Eastern Province
FL-ASS	Flameless Atomic Absorption Spectrophotometer
GC-ECD	Gas Chromatography-Electron Capture Detector
GC-MS	Gas Chromatography-Mass Spectrometer
GDP	Gross Domestic Product
GSFMO	Grain Silos & Flour Mills Organization
HPLC	High Performance Liquid Chromatography
IC	Ion Chromatography
ICP-MS	Inductively Coupled Plasma-Mass Spectrometer
IOC	Intergovernmental Oceanographic Commission
ISA	Intensive Study Area
IUCN	The World Conservation Union
ITCZ	Inter Tropical Convergence Zone
JICA	Japan International Cooperation Agency
KFUPM	King Fahad University Petroleum and Minerals
KSA	Kingdom of Saudi Arabia
MAW	Ministry of Agriculture and Water
MEPA	Meteorology and Environmental Protection Administration
NCWCD	National Commission for Wild Life conservation and Development
OJT	On the Job Training
ORP	Oxidation Reduction Potential
PERSUGA	Regional Organizations of the Red Sea and Gulf of Aden
PETROMIN	General Petroleum and Minerals Organization
QA/QC	Quality Assurance /Quality Control
RCJY	Royal Commission for Jubail and Yanbu
ROPME	The Regional Organization for the Protection of the Marine Environment
SABIC	Saudi Basic Industries Corporation
SAFCO	Saudi Fertilizer Company
SCH	Saudi Consulting House
STP	Sewerage Treatment Plant
TDS	Total Dissolved Solids
TKN	Total Kjeldahl Nitrogen
T-N	Total Nitrogen
T-P	Total Phosphorus
TOC	Total Organic Carbon
TSS	Total Suspended Solids
UNEP	United Nations Environment Program
VOC	Volatile Organic Carbon

SUMMARY

SUMMARY

1. Objectives

The objectives of this project is addressed in, through implementation of actual sea water monitoring along the Arabian Gulf, the following three issues.

1. to examine seawater quality and to identify causes of water quality degradation along the Arabian Gulf;
2. to review the existing sea water quality monitoring activities conducted by MEPA and by other parties, and to help develop a more comprehensive, integrated and appropriate sea water quality monitoring system;
3. to strengthen MEPA 's capacity for managing environment particularly along the Arabian Gulf through technology transfer to counterpart personnel during the course of the Study.

2. Study Area

The study area was identified to be the sea and coastal areas along the Saudi Arabian Coast of the Arabian Gulf.

Following the preparative site inspection undertaken in accordance with MEPA's suggestions and subsequent discussion, the Team agreed to expand the proposed Intensive Study Area that in between north of Jazirat Abu Ali Area (North Point) and Ras Al Qurayyah Area (South Point).

3. Result of the Study

3.1 Marine Pollution Investigation

(1) Collection and review of existing data/information

Data and information concerned with the natural environment, ecology, economical activities and pollution condition and environmental management of Arabian Gulf were collected and summarized.

Distribution of main pollution sources and important habitats were also clarified from the collected information including MEPA's GIS Map. These information can be used for planning future marine monitoring programs and studies.

(2) Marine Monitoring Survey

For the purpose of understanding the pollution condition of the intensive study area, two rounds of water quality monitoring in the pilot monitoring area (Intensive Study Area) were conducted in October-November, 1999 and June-July, 2000.

A total of 34 sampling sites were selected for these monitoring survey. Collected samples are analyzed in the Laboratory of MEPA Eastern Province by using the

equipment donated by JICA.

The result of monitoring survey showed that the high concentration of nutrients (i.e. Nitrogen and/or Phosphorous) was detected in some limited area proximity of industrial discharge. High concentration of metals (i.e. Cr, Cd, Cu, Hg, Ni, Pb, V, Zn) and TPH were also detected in the sediment of these area.

These results suggest that the effluents from the land may affect the surrounding water body and may possible to cause eutrophication in the future. For further understanding and prediction of the nutrients influence, it will be needed to know the trend of water quality degradation and seasonal change based on the water quality monitoring implemented regularly.

(3) Satellite Image Analysis

Satellite image data covering Arabian Gulf were analyzed. And then the following maps, indicating the condition of water pollution, were created.

- Suspended Solid Distribution map
- Chlorophyll Distribution map
- Oil Pollution Distribution map
- Temperature Distribution map
- Coastal Areas Distribution map

The apparent trend of temperature, SS and chlorophyll distribution estimated from the maps corresponded to the 1st round water monitoring survey results.

On the other hand, the oil distribution map dose not seen to correspond to the survey results.

The analysis results the effectiveness of the satellite image data for providing a synoptic and quantitative overview of the water quality in the Intensive Study Area.

3.2 Study for the Recommendation on Future Monitoring System

(1) Existing monitoring systems

Existing monitoring systems were reviewed using collected data and information. Only one case of continuous marine monitoring in Arabian Gulf is conducted by Royal Commission mainly in Al Jubayl area.

The future monitoring plan in the Arabian Gulf should be recommended by considering the exchange of data and information with other organizations relating to the activities of coastal zone management.

(2) Recommendation on the future monitoring system in the Gulf

Comprehensive monitoring systems were proposed as a goal of future monitoring system in the Gulf.

In order to approach to these purposes, four steps are assumed as follows;

Phase I: The present phase which MEPA/JICA project is completed,

Phase II: The phase to consolidate the system developed in the previous phase,

Phase III: The phase to enhance the developed system and to apply to other areas, and,

Phase IV: The final phase to complete all components proposed.

All these phases are planned to be completed for a period of two years.

The Study Team and MEPA understand that the intention of implementing MEPA's duty and the support of donors like Japan will be highly required to realize the above plan.

3.3 Strengthening of MEPA's Capability

(1) Implementation of MEPA's laboratory

With the cooperation by MEPA Eastern Province, the laboratory and field equipment supplied by JICA via purchases within the Kingdom has been installed in the laboratory of MEPA Eastern Province, and basic technological transfer for how to use laboratory equipment to C/P was conducted.

Documents and papers needed for laboratory analyses and management, i.e., Sample check list, Data Sheet, Health and Safety Plan, Analysis Procedure Sheet etc. were also prepared.

(2) Recommendation about organization and administration

It is considered that MEPA E. P. needs to improve the following items to enhance its marine monitoring capability.

- to clarify the precise marine management objectives and strategy of the MEPA E.P.;
- to define and balance budget needs and constraints;
- to collaborate, coordinate and integrate with other environmental related organizations;
- to review and develop its strategy, policies and legislative basis for marine environmental management; and
- to collaborate with other Gulf countries to conserve Gulf environment.

(3) Technology Transfer

Following technology transfer works were conducted as under the name of On-the-

Job-Training (OJT), lecture and discussion with C/P.

Laboratory works

- Basics of chemistry and laboratory work
- Sample receiving and sample custody method
- Chemical analysis work
- Data analysis (calculation and Data handling)
- Reporting of result
- Other management items

Field monitoring works

- Basics of monitoring plan design
- Planning of Health and safety plan for field works
- Sample management methods
- Data analysis (calculation and Data handling)
- Sampling plan design
- Preparation works for field monitoring
- Recording of monitoring result
- Chain of custody procedure

Administrative work

- Discussion with MEPA E. P. staffs about the administration and management system of MEPA.

Satellite Image Analysis

- Basic theory of the Satellite Image Analysis

1. INTRODUCTION

1. INTRODUCTION

This report summarizes the main report of the MEPA (Meteorology & Environmental Protection Administration) -JICA (Japan International Cooperation Agency) joint project entitled "The Study in an environmental Assessment and Monitoring of Arabian Gulf in the Kingdom of Saudi Arabia" which is enhancing MEPA's marine monitoring and management capability for the coastal water of the Arabian Gulf.

The JICA study team (hereinafter referred to as the Team) and MEPA Eastern Province (hereinafter referred to as MEPA EP) worked on various activities including collection of existing data and information, field monitoring, laboratory work and visiting to other organizations for the progress of the Study in accordance with the planned program (see Figure 1).

All works in each work stage of this project can be described briefly below.

(1) First Work Stage in Japan (February, 1999)

Based on the Preliminary Report prepared by JICA in February 1999 and other information obtained by the Team, an inception report has been prepared. Both the basic concepts of the Study and individual methods proposed for each task and/or technology transfer was included in this inception report.

In order to identify the characteristics of seawater in the Gulf, the analysis of satellite photography has been implemented.

(2) First Work Stage in Saudi Arabia (March, 1999)

The outline of the Study has been developed in accordance with the technical discussion with MEPA. And the framework construction of study plan has finalized. Key features of this stage are shown below:

- 1) The data and/or information were obtained through MEPA.
- 2) The Team reviewed the present status and capabilities of the laboratory in MEPA EP.
- 3) Responsibility and roles of both the Team and MEPA was discussed and defined.
- 4) Based on the above work, a list of equipment necessary for the Study was proposed. The study plan was also decided through technical discussion between the Team and MEPA EP. The Team had proposed the study area from Ras Tanurah to Al-Khobar while MEPA EP emphasized to extend this area from Al-Jubail to Al-Qurrayah. Based on above discussion an intensive study area was finalized by both the Team

and MEPA EP that includes the offshore area of AL-Jubail, Ras Tanurah, Al-Qatif, Al-Dammam, Al-Khobar and Al-Qurraiyah.

(3) Second Work Stage in Japan (May, 1999)

Based on all information and data obtained during the course of the First Work Stage in Saudi Arabia, various preparation works were be started.

(4) Second Work Stage in Saudi Arabia (June - July, 1999)

Preparative field inspection was conducted by both the Team and MEPA EP. along the eastern coast, i.e. from Al-Khafgi, at north to the south of Al-Qurraiyah. The planning of environmental monitoring along the Gulf was also conducted.

(5) Third Work Stage in Saudi Arabia (September - November, 1999)

The first round of water quality monitoring was conducted during the third stage. During the course of each operation, all technologies, which the Team can handle, were tried to transfer from the Team to MEPA counterpart.

A set of Analytical Equipment purchased by JICA was installed in the laboratory of MEPA EP.

(6) Third Work Stage in Japan (January – February, 2000)

The Draft Interim Report was prepared during the period of Third Work Stage in Japan.

According to the request by Study Team, Mr. Aziz Al-Omari, who was invited by JICA, Tokyo expressed his valuable discussions and comments on this report during his stay in Japan.

(7) Fourth Work Stage in Saudi Arabia (May – July, 2000)

The activity of this stage was implemented dividing into two parts; the second round of field monitoring and the planning and consolidation of the 'Guideline of Water Quality Monitoring along Arabian Gulf'.

1) Second Round of Field Monitoring

The second round of field monitoring was implemented in June, 2000.

The Team and MEPA have evaluated the results of monitoring. In addition to the above activities, the analysis of satellite photography was implemented.

2) Discussion on ' Guidelines for Water Quality Monitoring of Arabian Gulf '.

The Team and MEPA has discussed the ' Guidelines of Water Quality Monitoring of Arabian Gulf ' proposed by the Team.

(8) Fourth Work Stage in Japan (September, 2000)

Preparation work for a Seminar expected has been held for the next work stage in Saudi Arabia. Also the draft final report have also been prepared.

(9) Fifth Work Stage in Saudi Arabia (November, 2000)

1) Discussion on Draft Final Report

The Team and MEPA reviewed the Draft-Final Report and made discussions to finalize it.

2) Seminar

The Team and MEPA have organized and promoted a cooperative seminar, and invited personnel and staff from governmental organizations as well as private companies related to this project.

The purpose of this seminar was present the results of the Study, and to discuss the future prospect and how to proceed the management of the coastal environment along the Saudi Arabian Coast of the Gulf.

(10) Fifth Work Stage in Japan (December, 2000)

Fifty (50) sets of final report was prepared and sent to MEPA from JICA.

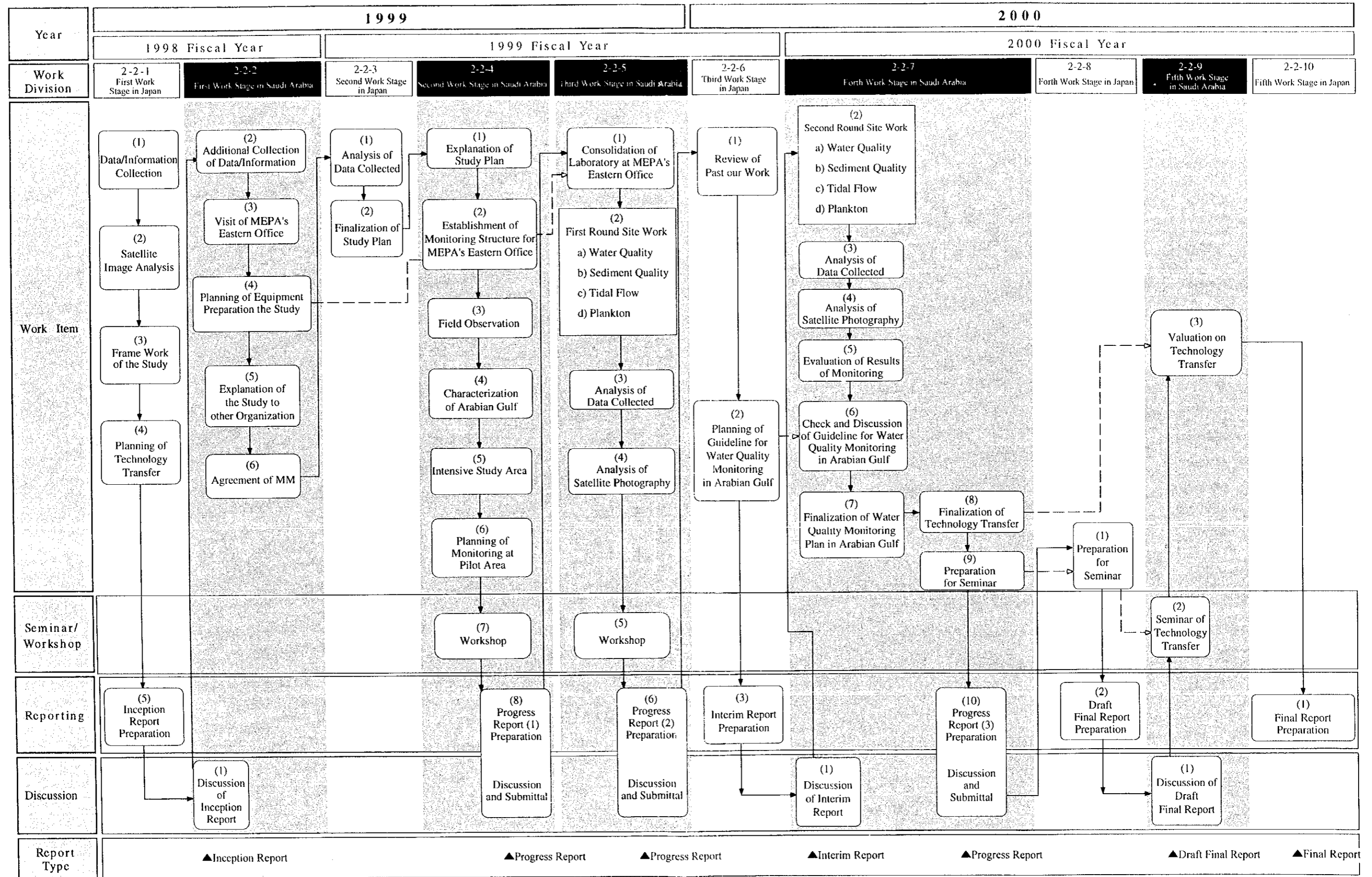


Figure 1 Work Flow

**2. MARINE POLLUTION
INVESTIGATION**

2. MARINE POLLUTION INVESTIGATION

2.1 Collection and review of existing data/information

Data and information concerned with the natural environment, ecology, economical activities and pollution condition and environmental management of Arabian Gulf were collected and summarized.

Distribution of main pollution sources and important habitats are also clarified from collected information and MEPA's GIS Map. These information have been used for planning future marine monitoring programs and studies.

2.1.1 Environmental Condition of the Gulf

(1) Characteristic of the Gulf (General)

According to C. Sheppard, et al (Marine Ecology of the Arabian Region, Academic Press), it is understood that the Gulf is a strongly sedimentary province with a dominating soft substrate benthos. Sediments of biogenic carbonates exist over much of the Gulf floor, with strong influences limited to the northwest end where the waterway of the Shatt al Arab discharges into the Gulf.

The Gulf is commonly divided into eastern and western sections by the Qatar peninsula although there is in fact a strong similarity of geological character on both sides of the latter. Offshore, underlying salt domes have forced upwards numerous islands and banks of hard substrate which are now colonized by corals. At the shoreline along the Arabian side, there is a very gradual slope and a gradual blending of marine conditions with terrestrial, sometimes extending across a band of several kilometers. This contrasts with the Iranian side where the Zagros mountains exceed 1000 m elevation close to the shoreline.

(2) Meteorology

Table 1 indicates climatological characteristics observed at Dhahran in KSA.

The extremely arid nature of the region, high temperatures and constant and intense sunshine, especially along coastal areas, gives the overall impression of a lack of seasonal variability.

Table 1 Monthly Meteorological Condition of Dhahran in 1997 AD

Element	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Spt	Oct	Nov	Dec
Average Air Pressure in millibars	1007	1014.9	1015.4	1010.8	1008.2	1004.9	997.7	994.3	997.4	1003.1	1009.4	1013	1015.3
Average Temperature in Centigrade	26	16.4	15.9	18.5	23.7	31.1	34.6	36.1	34.7	32.5	29.1	21.9	17.7
Average maximum Temperature	22.8	21.9	23.8	30.1	38.7	43.1	43.5	41.5	41	36.7	26.7	22.9	32.7
Extreme maximum Temperature	-	27.6	29.6	30	36.5	44.6	48.2	46	46	44.4	43	32	26.3
Average minimum Temperature	20.2	10.7	10.7	14	18.2	24	27.1	29.7	28.7	25	23.3	17.8	13.2
Minimum Temperature	-	6.1	6.2	7.4	12.1	18.4	23.3	27	23.4	19.8	19	13	6
Average Relative Humidity in Percent	52.6	66	55	66	54	37	39	32	35	47	58	72	70
Maximum R/H	-	100	91	98	96	82	86	88	84	95	98	96	97
Minimum R/H	-	21	18	20	14	11	9	12	14	7	13	34	22
Number of Rainy Days	72	11	1	26	2	1	0	0	0	0	3	18	10
Rainfall amount (mm)	187.1	11.7	-	44.6	1	0.7	-	-	0	0	1	121	7.1
Wind Direction	-	WNW	N	N	N	N	N	N	N	N	N	WNW	WNW
Wind Speed in Knots	-	6	9	9	8	7	8	10	11	8	7	8	8
Number of Days with sandstorm	1	0	0	0	0	0	0	0	0	0	0	1	0
Number of Days with thunderstorm	20	3	0	8	1	1	0	0	0	0	0	7	0
Number of Days with fog	24	12	0	2	3	0	0	0	0	1	6	0	0

Source: Statistical Yearbook for 1417 H (1997 AD)
by the Central Department of Statistics in the Kingdom of Saudi Arabia

(3) Oceanography

The main, broad scale circulation in the Gulf, or the residual current (current remaining after tidal currents are removed) is an anti-clockwise rotation, affected to some degree by the projection of the Qatar peninsula.

Figure 2 indicates the schematic of surface currents and circulation processes in the Gulf. Following are explanation of this figure related to the Saudi Arabian Coast by Reynolds (1993).

- The figure indicates the mean winter time surface current pattern which is the most widely known current pattern.
- The flow is predominantly density driven with surface flow inward from the Strait of Hormuz and adjacent to the Iranian coast.
- A southward coastal flow is present along the entire southern coast of the gulf.
- The northern gulf circulation is predominantly wind driven, with the surface flow along both coasts in a southerly direction.
- Outflow from the Shatt Al-Arab is carried by the counter-clockwise circulation in a westerly direction and down the Kuwait and Saudi Arabian coast.

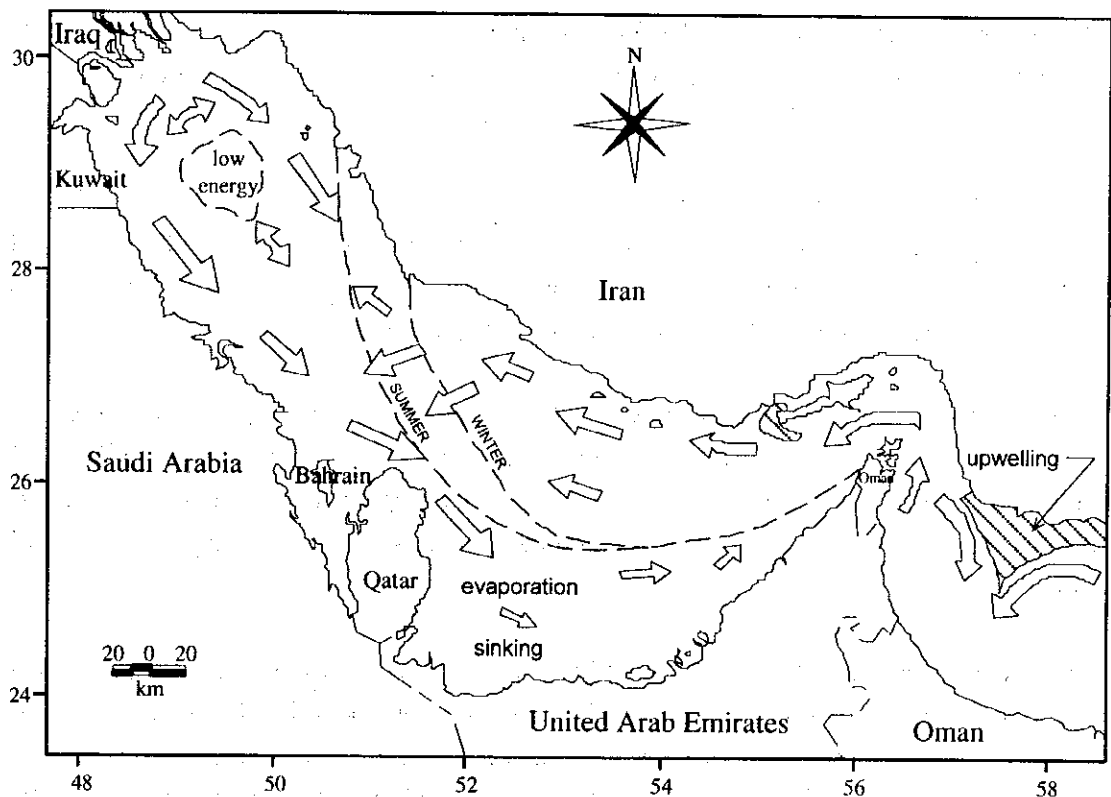


Figure 2 Schematic of surface currents and circulation processes (Michael Reynolds, 1993)

2.1.2 Economical Condition / Industrial Structure

(1) Economy in General

The government of Kingdom of Saudi Arabia (KSA) has been exerting its effort to diversify the economy in the past three decades from the crude oil industry and has achieved a successful diversification. As the result, besides oil products, there are many areas in a considerable progress such as petrochemical products, plastics, fertilizer, basic metal, steel, cement, furniture as well as achievement of self-supply of wheat and other vegetables in the agricultural industry in line with the development of infrastructure such as supply of water, electricity, gas and communications, transportation by air and surface road. Thus the oil sector in the GDP comparably decreased its ratio to 34.8% in 1998 from 58.9% in 1970. (WEIS Report, Sept.1999). The above achievements have been carried out through the Five Year Plans which commenced in 1970 and currently entered into the 6th plan.

- **The first Five-Year Development Plan (1970~1975)** had several general economic and social goals. Among others, the most significant goal was to increase the role of the non-oil sector of the economy.

-**The second development plan (1975~1980)** included such goals as to attain a high rate of economic growth, to reduce dependence on oil, to develop human resources, to raise the standard of living, and to develop the physical infrastructure.

-**The third development plan (1980~1990)** emphasized growth in agriculture, industry, and mining, while stressing the control of the expatriate labor force and achievement of maximum effectiveness in Saudi human resources training and development, in addition to the continuous efforts on the goals of the second development plan.

-**The fourth development plan (1985~1990)** emphasized increasing productivity and efficiency of the economy, the promotion and execution of economic and social integration within the GCC countries, reduction of dependence on expatriate labor, underlined the significance of the role which the private sector had to play in the overall economy of the country.

-**The fifth development plan (1990~1995)** was designed to continue the long term objectives of the previous plan, especially emphasis on the role of private sector to participate in the growth and industrialization, on creation of job opportunities for the Saudi work force, and local production to replace foreign imports and increase export and improve the balance of payment.

-The sixth development plan (1995~2000) continuously stresses the importance of effectiveness of the private sector and sets a goal of privatization of public sector companies such as those for telecommunication, aviation, SABIC group etc., though the implementation of the goal has not been satisfactorily achieved. The job creation for the Saudi nationals is also an impending goal in the wake of increasing number of young Saudi people who look for new jobs. Replacement of expatriate labor force for Saudi nationals and training of Saudis for higher skills are regarded indispensable in the plan. (Reference: Top 1000 Saudi Companies 5th Edition 1997~98)

(2) Economic Structure

The GDP of Saudi Arabia as of 1998 is approximately 128.9 billion US dollars (World Bank database July, 2000). The principal sector is oil, natural gas and minerals for 38%. The second is the public services for 18 %. Thirdly manufacturing including oil and petrochemical products for 10%, likewise construction 8%, agriculture 6%, commerce and services 6%, transportation, ware-housing and communication 6%, finance, insurance and real estate services 5 % and others 3%.

In 1998, Saudi Monetary Agency estimates the oil sector shares 34.8% of GDP and non-oil sector 65.2% out of which 40.1% attributes to the private sector, and 25.1% to the public sector respectively. The non-oil sector attained an annual average growth rate at 6.3% since 1970 (see Table 2).

Table 2 GDP Structure as of 1997

Unit: 100 million US Dollars (exchange rate: 3.74 Riyals/US\$)

	1994	1995	1996	1997 (%)
Crude Oil, Gas etc.	39,863	42,606	49,516	54,425 (38)
Industry	10,554	11,412	12,741	13,967 (10)
Oil Products	(4,195)	(4,512)	(5,223)	(5,803)
Others	(6,359)	(6,900)	(7,518)	(3,164)
Construction	11,425	11,630	11,884	12,383 (8)
Agriculture/Fishery	8,323	8,449	8,599	8,857 (6)
Commerce, Hotel	8,818	8,862	9,160	9,389 (6)
Transport etc.,	8,143	8,266	8,424	8,719 (6)
Finance etc.,	5,371	7,347	7,487	7,751 (5)
Public Services	21,417	23,060	24,172	25,998 (18)
Others	6,413	4,224	4,737	4,878 (3)
Total	120,327	125,856	136,720	146,367 (100)

Source: WEIS ARC Report

(3) Industries in Eastern Province

1) Industries

Since 1938 when a large quantity of oil was discovered in Dammman, the Eastern Province has been the center of attractions for the government of KSA as well as for the world. As seen above, the government first exploited crude oil, and then refined it to oil products including petrochemicals and now has made a great progress of diversification of the industries through SABIC. Most of these industries are located in the Eastern Province, though Yanbu on the Red Sea side, Riyadh and other areas have been largely developed in line with the government policy of nation-wide diversification of the national economic centers. In order to facilitate the new industries, Royal Commission for Jubail and Yanbu accommodates them in its industrial cities, providing all necessary infra-structural services.

The principal industries in the Eastern Province are listed as follows:

- Refinery and NLG Plant

Aramco refinery/NLG complex including a terminal of oil/ LNG, Ras Tanura. Saudi
Aramco/Shell Refinery Co., Al-Jubail

- Petrochemical Plant

Al Jubail Petrochemical Co.,
Eastern Petrochemical Co., Al Jubail
Arabian Petrochemical Co., Al Jubail
National Methanol Co., Al Jubail

- Metal/Steel Plant

Saudi Iron and Steel Co., Al Jubail
Zamil Steel Buildings Co. Ltd., Damman

- Chemical Fertilizer Plant

Al Jubail Fertilizer Co., Al Jubail
Saudi Arabian Fertilizer Co., Dahran

- Water Desalination and Power Generation Plant

Saline Water Conversion Corporation, Al Jubail
Saudi Consolidated Electric Co., in the Eastern Province, Damman
General Electricity Corporation

- Plastic Products Factory
 National Plastic Co., Al Jubail
 Saudi Plastic Products Co Ltd., Damman

- Cement Plant
 Eastern Province Cement Co., Damman
 Saudi Cement Co., Damman

- Others
 National Paper Products Company-Damman, Damman
 Saudi Fisheries Co., Damman
 Arabian Geophysical and Survey Co., Al Khobar

The above companies are selected from the view point of the industrial policy of the Kingdom. Trading companies, construction companies, retailers and other service companies are widely established in the Eastern province as secondary and tertiary sectors in the wake of the above basic industries. The major companies of all trades in the side of Eastern Province are shown in The attached data book.

2) Industrial Features in Eastern Province

Analysis from the data from "Top 1000 Saudi Companies Fifth Edition 1997-98" Indicates that there are many types of companies in this province, however the Manufacturing sector, especially extraction of crude oil and oil refineries is dominant in terms of economic size (turnover) which is almost equivalent to 90% of total economy in the region. On the other hand, in terms of job creation, the other sector (construction, commerce and service) undertakes almost 60% of total employment, while the manufacturing sector takes 40%. In this sense, construction and service companies can be regarded as a most reliable source to offer job opportunities to the young Saudi people, particularly because those types of jobs are currently taken extensively by the expatriates. It is indicated that diversification of economy will expand possibility of saudization of human resources which is also one of important goals of KSA(For detail, refer to Table 3).

Table 3 Ratio of Manufacturing Companies to All Companies

	Number of Companies	Number of Employee	Turnover (SR)
Manufacturing	88	96,859	175,136,843,051
All Company	247	245,323	200,544,716,185
Ratio (%)	36%	39%	87%

Source: Top 1000 Saudi Companies

3) Industrial Impact on Environment

Al-Jubail, Damman, Daharan, and Al-Khobar, which make up the core center of Saudi industrialization, are located in within a 200km zone on the eastern coast. Major Manufacturing Companies exist in this area are shown in Table 4. All these factories could be potential sources of pollutants, more or less, to the environment, regardless how strictly the pollutants are controlled within the compound of the factories. Based upon project experiences conducted by Chiyoda Dames and Moore, the possibility of pollutants varies depending upon the nature of the factories and may include metals, oil & grease, residual chlorine, alkaline, nitrogen, phosphate, phenol, sulfide, acid, organic substances, etc., In relation with the manufacturing factories, possible sources of pollutants in those cities are assumed and listed in Table 5.

Table 4 Major Manufacturing Companies in Saudi EP

Group No.	Kind of Manufacturing	Number of Companies	Ratio (%)	Number of Employee	Ratio (%)	Turnover (SR)	Ratio (%)
12	Food	6	6.82%	6,998	7.22%	4,160,500,000	2.38%
13	Beverage/Fodder/Cigarette	1	1.14%	61	0.06%	22,831,719	0.01%
14	Textile (Excluding Fabrics)	1	1.14%	66	0.07%	25,000,000	0.01%
17	Furniture	2	2.27%	392	0.40%	75,000,000	0.04%
18	Pulp/Paper	5	5.68%	1,120	1.16%	575,279,000	0.33%
20	Chemicals	16	18.18%	4,879	5.04%	4,903,132,000	2.80%
21	Oil and Coal Products	2	2.27%	59,000	60.91%	157,580,000,000	89.98%
22	Plastic	9	10.23%	2,878	2.97%	775,500,000	0.44%
25	Ceramic/Soil and Stone Products	11	12.50%	6,208	6.41%	1,886,917,691	1.08%
26	Steel	2	2.27%	396	0.41%	238,646,000	0.14%
27	Metal excluding Steel	1	1.14%	35	0.04%	21,000,000	0.01%
28	Metal Products	17	19.32%	8,336	8.61%	2,636,036,641	1.51%
29	Machine	5	5.68%	3,320	3.43%	794,000,000	0.45%
30	Electrical Machine	7	7.95%	1,960	2.02%	658,000,000	0.38%
34	Other Products (Jewellery, Music Instruments, etc.)	1	1.14%	50	0.05%	25,000,000	0.01%
37	Gas	2	2.27%	1,160	1.20%	760,000,000	0.43%
Total		88	-	96,859	-	175,136,843,051	-

Source: Top 1000 Saudi Comp

Table 5 Major Possible Pollutants from Manufacturing Industry in Saudi EP

Group No.	Kind of Manufacturing	Location	Possible Pollutants	
12	Food	Dammam Daharan Alkhobar	Organic Substance Residual Chlorine	Oil & Grease
13	Beverage/ Fodder/ Cigarette	Dammam	Organic Substance Nitrogen	Oil & Grease Phosphorus
14	Textile (Excluding Fabrics)	Dammam	Organic Substance Nitrogen Residual Chlorine	Oil & Grease Phosphorus Metals (Cr)
17	Furniture	Dammam Alkhobar	Organic Substance Organic Solvent	Oil & Grease
18	Pulp/Paper	Dammam Alkhobar	Residual Chlorine	Oil & Grease
20	Chemicals	Dammam Jubail Alkhobar	Metals(Mn, Cr, Pb, Cd, Hg, Fe, Na, As) Organic Substance Oil&Grease Organic solvents (BTEX) Nitrogen (NH ₄ -N, NO ₃ -N)	Cyanide (CN) Phenols Phosphorus SS LAS
21	Oil and Coal Products	Daharan Khafji	Phenols Sulphide Organic Solvents (BTEX)	Nitrogen (NH ₄ -N) Cyanide (CN) Oil & Grease
22	Plastic	Dammam Alkhobar	Organic Solvents (BTEX)	Phosphorus
25	Ceramic/Soil and Stone Products	Dammam Jubail Daharan Alkhobar	Metals (Ca, Pb, Fe, Cd) Organic Solvents (BTEX)	SS Oil & Grease
26	Steel	Daharan Alkhobar	Metals (Fe, Cr, Pb, As, Fe, Hg) Cyanide (CN)	Oil & Grease SS
27	Metal excluding Steel	Jubail	Metals (Pb, As, Cu, Zn, Cd, Co, Fe, Al) Organic solvents	Oil & Grease
28	Metal Products	Dammam Jubail Daharan Alkhobar Sayhat	Metals(Cr, Mn, Zn, Fe, Ni, Pb, Cu, Sn) Organic solvents (BTEX)	Cyanide (CN) Nitrogen (NH ₄ -N)
29	Machine	Dammam Alkhobar	Organic Solvents	
30	Electrical Machine	Dammam Daharan Alkhobar	Metals(Hg, Pb, Cd, Ni, Hg, Sn, Zn) Organic Solvents (BTEX) Nitrogen (NH ₄ -N, NO ₃ -N)	Phosphorus (PO ₄ -P) Cyanide (CN)
34	Other Products (Jewellery, Music Instruments, etc.)	Dammam	Organic Solvents	
37	Gas	Dammam Alkhobar	Metals	Residual Chlorine