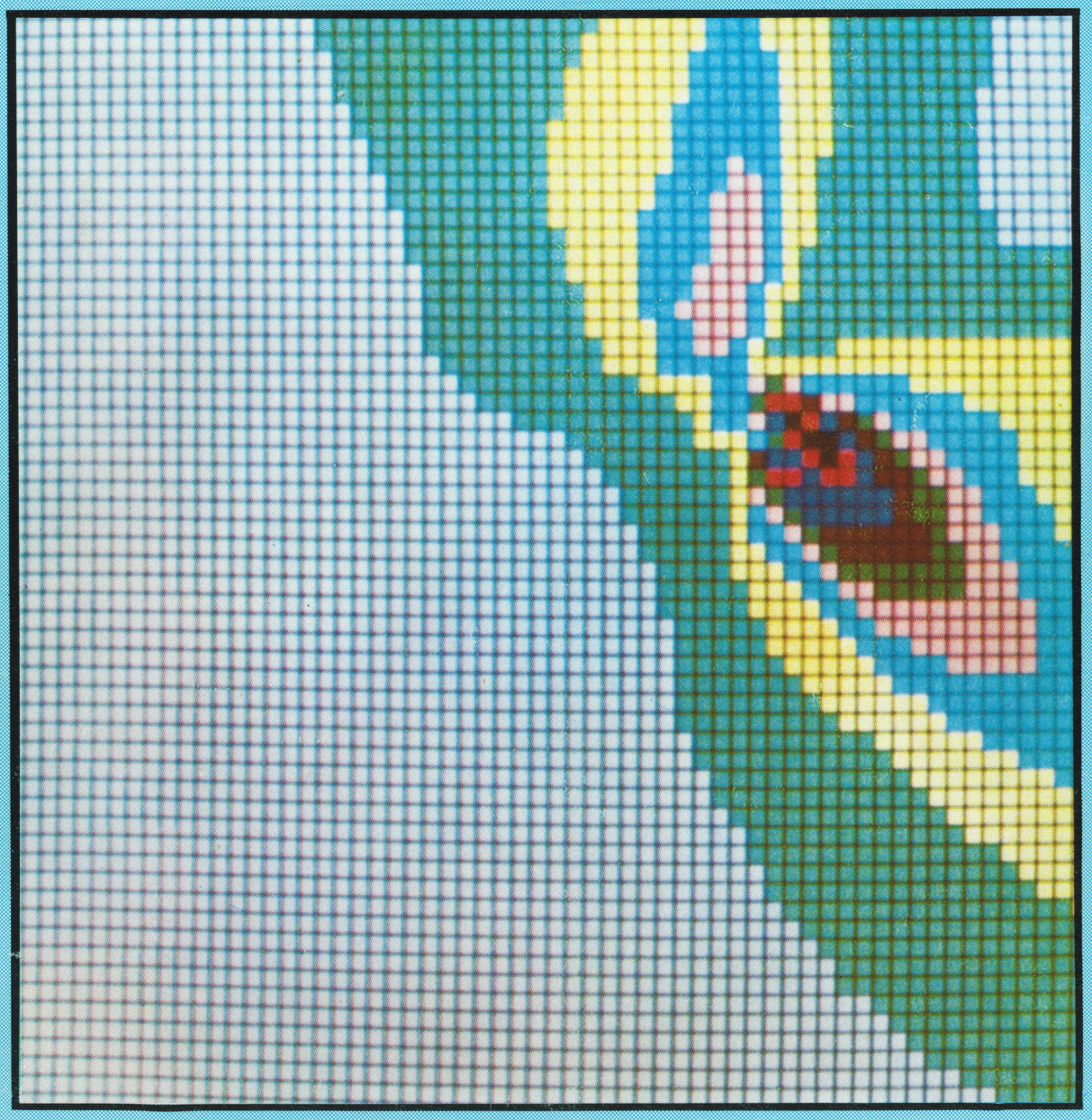
FINAL REPORT
Air pollution dispersion and prediction model for Shuaiba Industrial Area

EES-45

Volume I — Executive Summary



SUBMITTED TO: SHUAIBA AREA AUTHORITY

KUWAIT INSTITUTE FOR SCIENTIFIC RESEARCH
P. O. BOX 24885 SAFAT
KUWAIT

JULY 1983

The cover picture provides a graphic representation of the ground level NO_x concentration field in the Shuaiba region as simulated by a numerical diffusion computation; darker colors indicate higher concentrations. This picture was produced using the HAZIENDA image processing system at the Kuwait Scientific Center of IBM. We thank Mr. Jesus Rueda of IBM for the preparation and the production of this picture.

KISR 1090 A

FINAL REPORT

AIR POLLUTION DISPERSION AND PREDICTION MODEL FOR SHUAIBA INDUSTRIAL AREA

EES-45

VOLUME I

EXECUTIVE SUMMARY

P. Zannetti
M. Sudairawi
N. Al-Madani
N. El-Karmi

ENVIRONMENTAL SCIENCES DEPARTMENT
ENVIRONMENTAL AND EARTH SCIENCES DIVISION

"RESTRICTED"

SUBMITTED TO
SHUAIBA AREA ATHORITY

KUWAIT INSTITUTE FOR SCIENTIFIC RESEARCH
P. O. BOX 24885 SAFAT
KUWAIT

JULY 1983

ABSTRACT FORM

Title: Air Pollution Dispersion and Prediction Model for Shuaiba Industrial Area

Project No. (if applicable) EES-45

Author(s): P. Zannetti, M. Sudairawi, N. Al-Madani, N. El-Karmi

Division/Department: E.E.S/Env. Sci. Dept.

Type of Publication (circle one) : Proposal Interim Report / Final Report / Periodical Article Conference Paper Manual/Brochure Patent Application

Security Classification (circle one) : General / Restricted / Confidential

ABSTRACT (Summary of not more than 300 words, in English and Arabic)

This is Volume I of a five-volume final report and contains an Executive Summary of the Project "Air Pollution Dispersion and Prediction Model for Shuaiba Industrial Area." This project represents the first organized air pollution modelling research study in Kuwait and is considered the first step of a three-phase program in air pollution modeling development and application. This brief executive outline provides a summary description of project structures, objectives, methodologies and results. Conclusions and recommendations for further studies are also presented.

KEY WORDS Air Pollution, Computer Modeling

Signature

July 30/1983
Date

ABSTRACT FORM

Title: نموذج الانتشار والتنبؤ بالتلوث الجوى الخاص بمنطقة الشعيبة الصناعية

Project No. EES-45 (if applicable)

Author(s): ب . زانيتي، م. سيدراوى، ن. المدني، ن. الكرمي.

Division/Department: ادارة العلوم البيئية والارضية /

Type of Publication (circle one) : Proposal Interim Report **Final Report** Periodical Article Conference Paper Manual/Brochure Patent Application

Security Classification (circle one) : General **Restricted** Confidential

---

ABSTRACT (Summary of not more than 300 words, in English and Arabic)

هذا هو المجلد الاول من التقرير الختامي الذى يتضمن خمسة مجلدات تحتوى على موجز تنفيذى لمشروع نموذج الانتشار والتنبؤ بالتلوث الجوى الخاص بمنطقة الشعيبة الصناعية. ويمثل هذا المشروع أول دراسة بحثية منظمة لوضع نموذج لانتشار التلوث الجوى في الكويت. ويعتبر الخطوة الاولى من برنامج ذى ثلاث مراحل لتطوير وتطبيق نموذج لانتشار التلوث الجوى. وتقدم هذه النبذة التنفيذية الموجزة وصفا مختصرا للجوانب المشكلة للمشروع وأهدافه ومنهجياته ونتائجه كما تقدم خلاصات وتوصيات يستفاد منها في الدراسات المستقبلية.

KEY WORDS

تلوث الهواء ، صياغة النماذج بواسطة الحاسب الالي .

Signature

July 30 / 1983

Date

EES-45 PROJECT TEAM

Dr. P. Zannetti, Project Leader

SAA TEAM

Mr. F. Dorgham, Co-Project Leader

Mr. H. Al-Adhad, Supervisor

ENGINEERS

Mr. F. Marei

Mr. M. Pervez

Mr. M. Ghanem

PROGRAMMERS

Ms. S. Emara

TECHNICIANS

Mr. M. Saleem

Mr. A. Zudhi

Mr. H. Batros

Mr. M. Saeed

KISR TEAM

Mr. M. Al-Sudairawi, Leader, Tasks 1 and 2

Ms. N. Al-Madani, Leader, Task 3

Mr. A. O. El-Karmi, Leader, Task 4

STAFF TASKS 1 AND 2

Mr. M. Abuseil

Mr. D. Wooster

Mr. S. Mohammed

Mr. W. Kittaneh

Ms. S. Homaidan

Mr. S. Khalifa

STAFF TASKS 3 AND 4

Ms. M. Al-Attiah

Ms. M. Kortom

SECRETARIAL SUPPORT

Ms. M. D'Souza

OTHERS

Mr. M. Safar, Climatologist

Preface

This study deals with the major industrial air pollution problem in Kuwait. Before its industrialization, the air quality of Kuwait was adversely affected only by "natural" pollution in the form of dust episodes. With urban and industrial development, however, traffic and industrial activities are responsible for atmospheric discharges of huge quantities of pollutants (gases and particulates) having potentially serious adverse effects on human health, animals, vegetation, visibility and materials.

The importance of this situation fully justifies efforts in research and development to assess, using the most advanced technology, the air pollution phenomena and their ecological consequences. The same concern is shared by the Shuaiba Area Authority, the major sponsor of the present study, to whom we express our gratitude for its support of this pioneer research activity for Kuwait.

Table of Contents

Abstract

This is Volume I of a five-volume final report and contains an Executive Summary of the Project "Air Pollution Dispersion and Prediction Model for Shuaiba Industrial Area." This project represents the first organized air pollution modeling research study in Kuwait and is considered the first step of a three-phase program in air pollution modeling development and application. This brief executive outline provides a summary description of project structure, objectives, methodologies and results. Conclusions and recommendations for further studies are also presented.

Data collection and analysis, on one side, and model selection, application and development, on the other, have been the major activities of this project. In particular, diffusion computer models, which simulate, through numerical techniques, the diffusion properties of the atmosphere and its capability of diluting pollutants discharged in it, have been applied.

Among the major accomplishments of this study are:

1. The computerized collection of hourly meteorological data during the six-year period 1977-82.
2. The new emission inventory of the industrial stacks in Shuaiba, which updates the previous inventory by Cremer and Warner (1975).
3. The installation and adaptation of six computer diffusion models in the KISR computer (two of them have also been installed in the small SAA/EPC computer) and the successful training of SAA personnel in using such numerical techniques.
4. The actual diffusion simulation results in which long-term (seasonal, annual) and short-term (hourly) simulations provided ground level concentrations of five pollutants emitted by almost 200 industrial emission stacks.

The results of this study can help the SAA in planning future industrial developments, simulating possible accidental releases, defining least-cost emission reduction strategies, and identifying the major

contributors to present pollution levels. The final considerations outline the need for a continuation of air pollution studies in the Shuaiba Industrial Area and, in particular, the implementation of the next phase of this project. Such future activity should continue the data collection work, especially through the performance of special data collection campaigns such as stack source sampling and tracer diffusion experiments. Moreover, the collection of ambient air quality concentrations should allow a proper and satisfactory calibration/evaluation of the developed diffusion models. Finally, more advanced modeling techniques should be developed to fully simulate the complexities of Kuwait's meteorology and the possible chemical interactions among the different atmospheric pollutants in the region.

1. Introduction and Overview

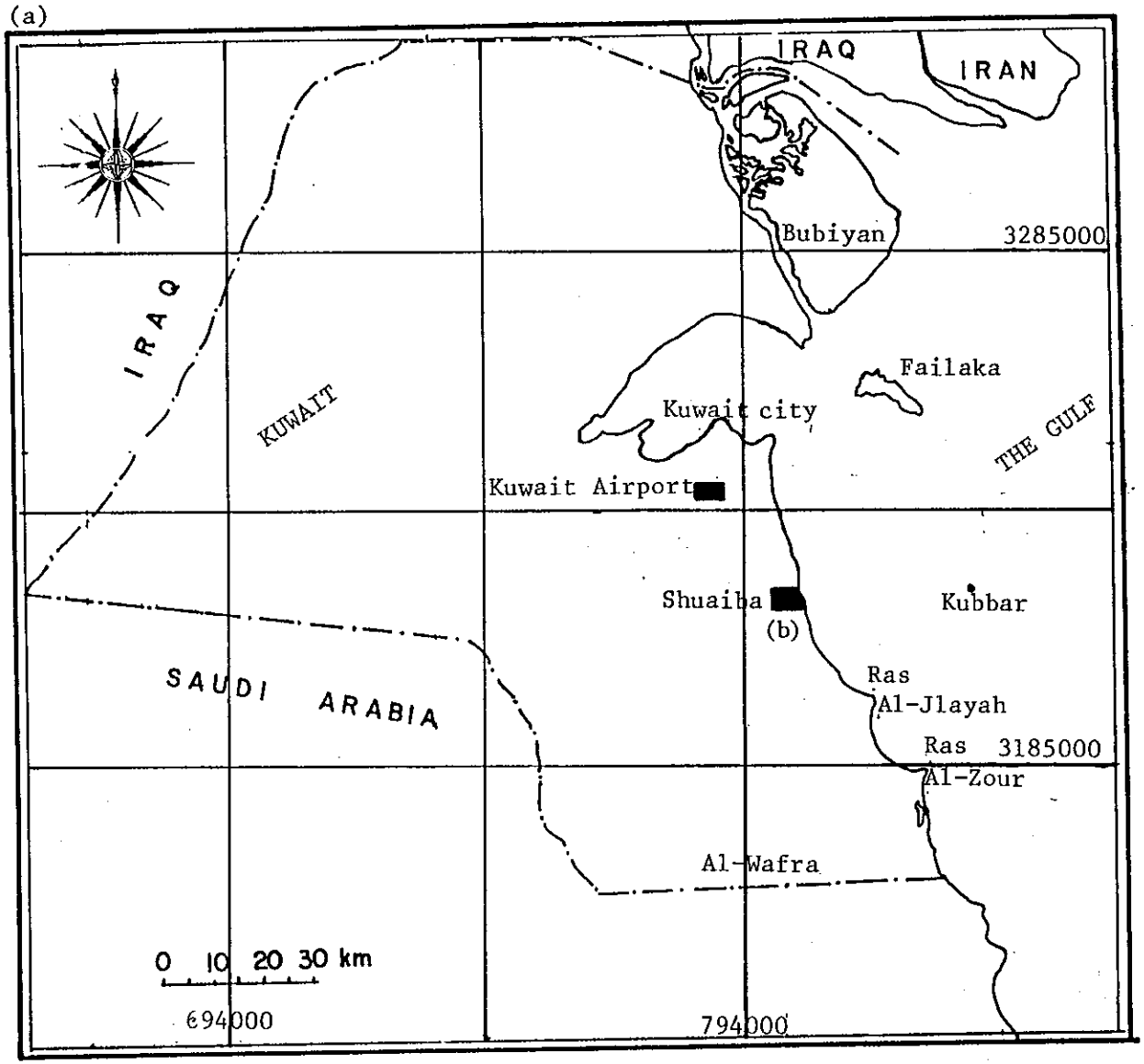
The Shuaiba Industrial Area (SIA), which, in this report, includes the industrial areas of Shuaiba, Al-Ahmadi and Mina Abdullah, is one of the largest industrial regions in the Arabian Gulf area (see Fig. 1). It is an important center for heavy industrial activities. The major companies in the region are:

- Kuwait National Petroleum Company, Shuaiba Refinery
- Kuwait National Petroleum Company, Mina Abdullah Refinery
- Kuwait Cement Company
- Kuwait Melamine Industries Company
- Petrochemical Industries Company (plants A and B)
- Shuaiba North Power Station
- Shuaiba South Power Station
- Lime Products Factory
- Kuwait Asbestos Industry
- Kuwait Oil Company

The atmospheric discharges from the SIA stacks are mainly composed of the following pollutants (in order of importance):

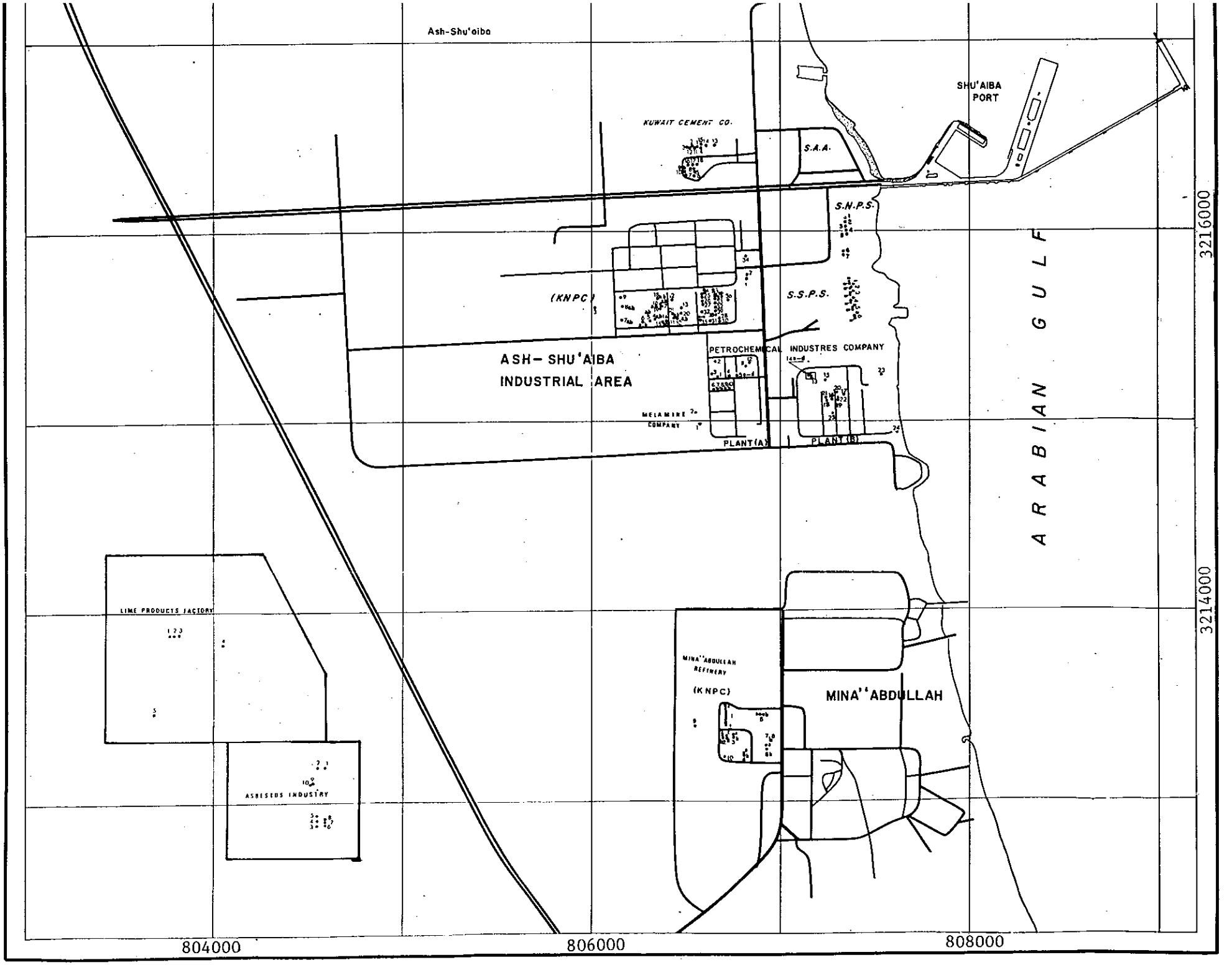
1) sulfur dioxide (SO_2), the most significant pollutant in the SIA;
2) particulate matter, especially
   - urea dust
   - cement dust;
3) ammonia (NH_3);
4) hydrogen sulfide (H_2S), mercaptans, hydrocarbons (HC); and
5) nitrogen oxides (NO_x).

Considering the potential health-related effects of these pollutants and the economical damages (e.g., corrosion) caused by them, it was imperative for Kuwait to start advanced air pollution studies, following the trend of most industrialized countries. The Shuaiba Area Authority (SAA), in particular, early recognized the need for the environmental planning of its industrial development and clearly identified air quality

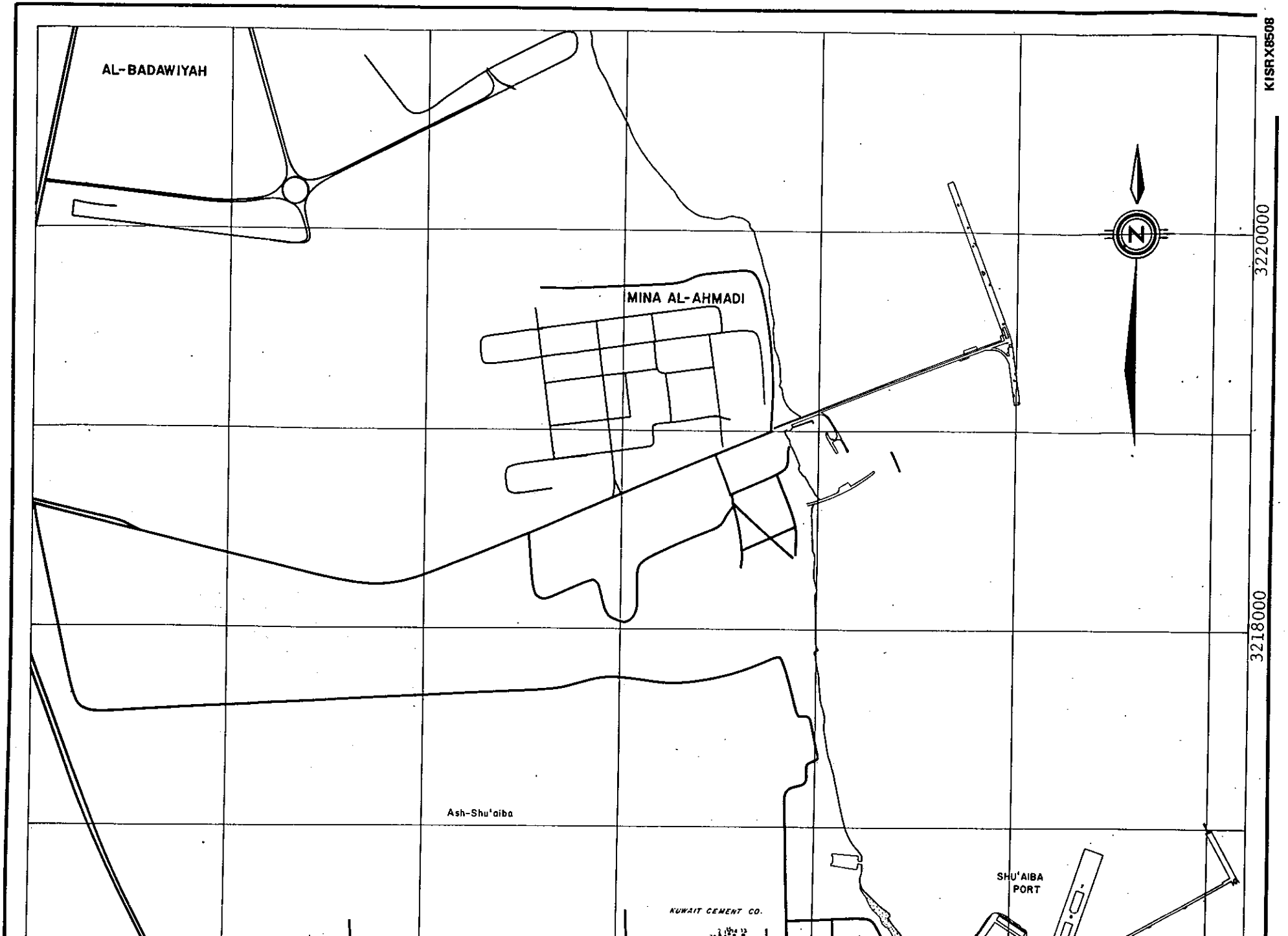


KISRX 8507

Fig. 1. The Kuwait region (a) and the Shuaiba Industrial Area (b)
(An enlargement of Area-(b) may be seen on the following page.)


Ash-Shu'aiba
SHU'AIBA PORT
KUWAIT CEMENT CO.
S.A.A.
S.N.P.S.
S.S.P.S.
(KNPC)
ASH- SHU'AIBA INDUSTRIAL AREA
PETROCHEMICAL INDUSTRES COMPANY
MELAMINE COMPANY
PLANT(A)
PLANT(B)
ARABIAN GULF
LIME PRODUCTS FACTORY
ASBESTOS INDUSTRY
MINA'ABDULLAH REFINERY
(KNPC)
MINA'ABDULLAH
3216000
3214000
804000
806000
808000

(b)


AL-BADAWIYAH
MINA AL-AHMADI
N
3220000
3218000
KISR X8508
Ash-Shu'aiba
KUWAIT CEMENT CO.
SHU'AIBA
PORT

as a key pollution problem in the SIA. It was further recognized that air pollution modeling techniques are the key numerical tool for any industrial development planning under the constraint of acceptable ambient air quality levels.

Consequently, the SAA, in its continuous effort to protect the local environment through scientific research and investigation, asked (SAA letter of June 18, 1980) the Kuwait Institute for Scientific Research (KISR) to formulate a joint SAA-KISR Air Pollution Study (APS) aimed at the following twelve major objectives for the SIA:

"1) to establish an Air Pollution Dispersion and Prediction Model for the Shuaiba Industrial Area;

2) to determine the most important parameters affecting the emission of pollutants, their modes of dispersion and performance;

3) to establish grid systems (or any other equivalent methodology) for the interpretation of the required results;

4) to assess the effectiveness of distances and heights of the major emitting facilities within Shuaiba Industrial Area and its vicinity;

5) to conduct experimental studies for the modes of transport of pollutants, their interaction, fall out patterns and dispersion;

6) to specify the needed effective heights of emission sources (with special reference to now and planned sources);

7) to predict and estimate short term and long term pollution episodes taking into account the nature of pollutants present in the area;

8) to simulate different conditions and compute their corresponding dispersion modes;

9) to evaluate, verify, and compare the model inputs and outputs;

10) to evaluate the performance, sensitivity and objectives of the model outputs;

11) to evaluate and critically assess all the model outputs in relation to measured established parameters; and

12) to recommend appropriate uses for the model in planning of industrial site allocation.)"

2. Project Objectives and Structure

In spite of some modifications during the 18-month study, the basic project structure and objectives, as described in the official KISR proposal, have remained unchanged. According to the proposal, the following main results were expected to be achieved:

1. The computerized collection and analysis of suitable data for both the present study and possible future air pollution investigations.
2. The installation and evaluation of several selected computer diffusion models.

To reach these goals, the study was structured into three tasks, and a fourth task was added during the study. These tasks are:

Task 1: Collection and preliminary analysis of existing data.

Task 2: Performance of additional measurements.

Task 3: Establishment of non-reactive dispersion and prediction models.

Task 4: Special data analysis and definition of a prototype data base.

Fig. 2 shows the schematic structure of this four-task activity.

3. Technical Approach and Methodology

3.1 Task 1--Collection of Available Data

A full investigation was made of the availability of relevant data in Kuwait. This was followed by making a systematic computerized collection of those data.

It was concluded that only the meteorological data collected at the Kuwait International Airport (KWI; see Fig. 1) showed the continuous reliability required for meaningful climatological analyses and long-term air pollution modeling applications. Both hourly ground level measurements

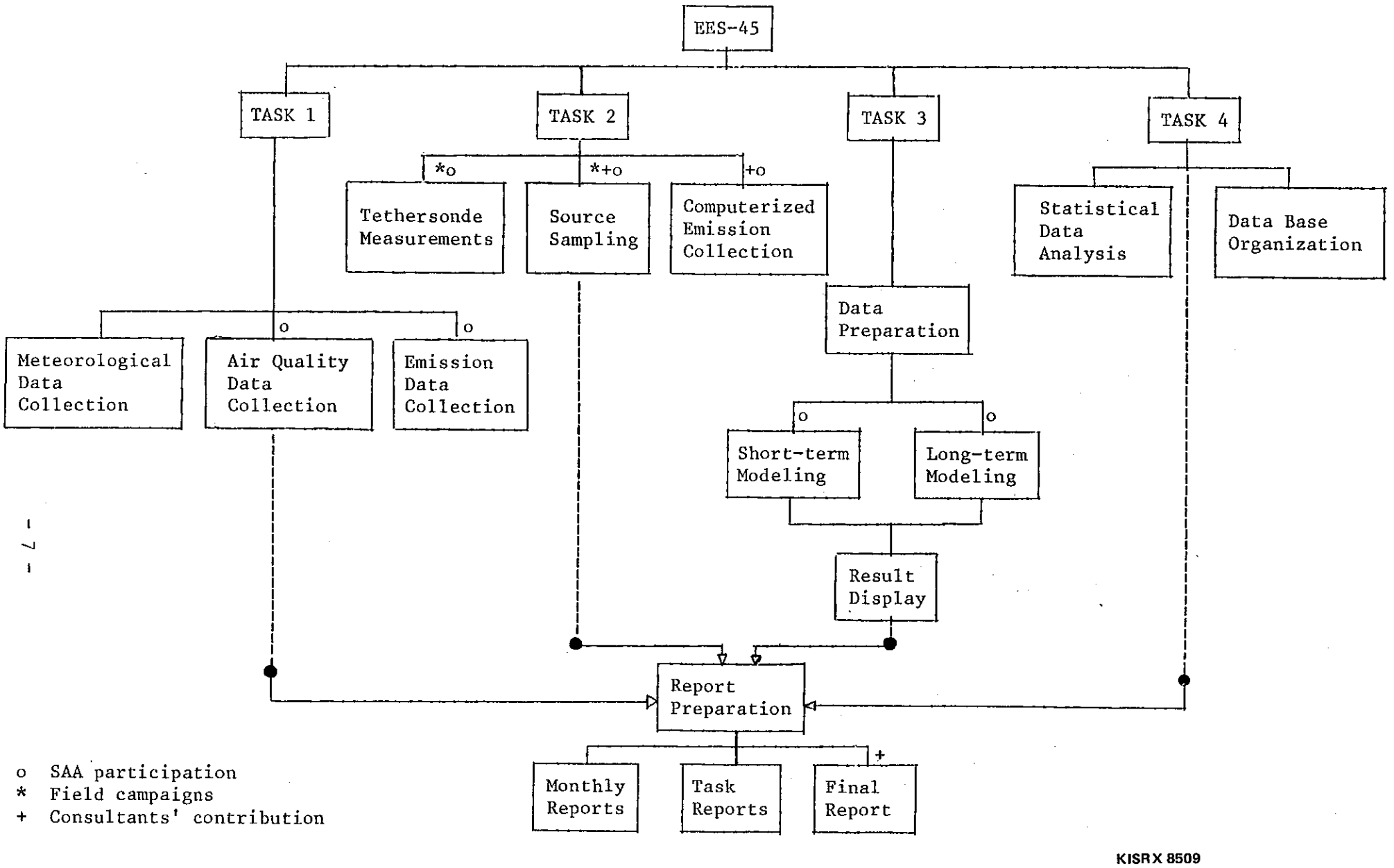


Fig. 2. EES-45 project structure.

(cloudiness, wind, weather, pressure, temperature, humidity, clouds, dew point) and twice a day vertical radiosonde measurements (inversions, winds, temperature, mixing height) were compiled for the six-year period 1977-82. A preliminary emission inventory of industrial stack discharges was also prepared.

3.2 Task 2--The Collection of New Data

As expected, Task 1 pointed out that more data were needed; therefore, special data collection activities were planned and executed.

In meteorology, hourly atmospheric stability and mixing height were computed from KWI measurements. Moreover, a tethersonde balloon instrument was purchased, tested and operated during a three-month (December 1982-February 1983) intensive monitoring campaign collecting vertical meteorological profiles (wind, temperature, pressure, humidity).

Some intense air quality measurements were performed during September-December 1982. The SAA/Environmental Protection Center (SAA/EPC) during this period increased the number of fixed monitoring stations to seven high-volume samplers for the measurement of daily average TSP (Total Suspended Particulate) concentration, and seven impingers for the measurement of daily average SO_2 and NH_3 concentrations.

Source sampling and evaluation activities were performed to finalize a reliable computerized emission inventory of major pollutants from SIA stacks. A consultant provided additional help and training in this delicate phase.

3.3 Task 3--Modeling Simulations

Modeling simulation represented the core of this study and six computer diffusion models were selected, installed on the KISR and SAA/EPC computers, applied and evaluated. Five of these models have been selected from the UNAMAP tape, which was obtained from the U.S. and contains computer diffusion codes specifically recommended by the U.S. Environmental Protection Agency for official regulatory air pollution diffusion simulations.

The industrial Source Complex Long-Term (ISCLT) model was identified as one of the most suitable techniques for long-term (climatological) model simulations that provide seasonal or yearly average concentration impacts of pollution emissions. An example of ISCLT results is displayed in Fig. 3, which shows SO_2 isopleths in the SIA.

3.4 Task 4--Data Analysis and Data Base

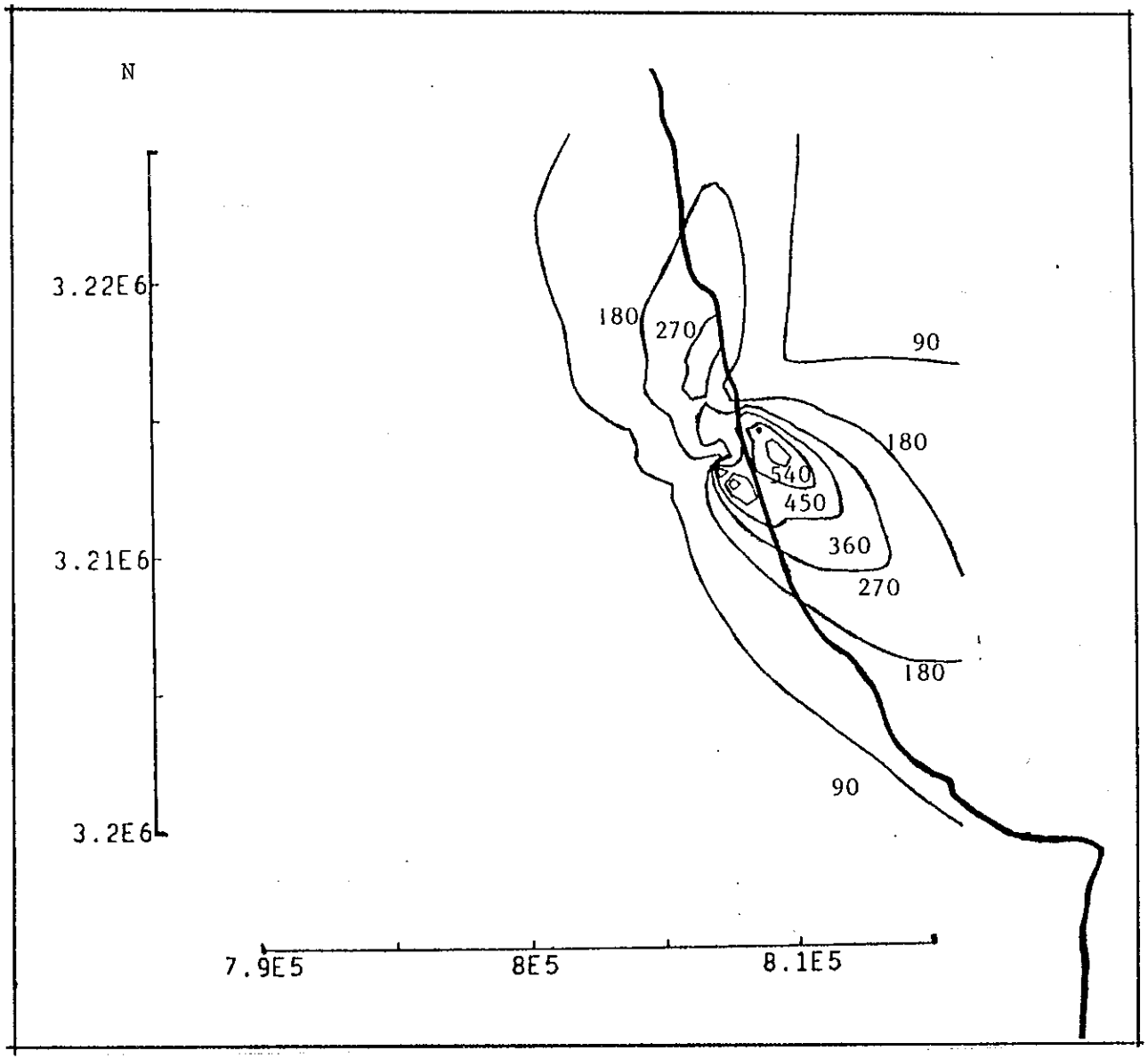
The huge amount of data collected in Tasks 1 and 2 required some additional effort in data analysis, which was basically performed through special studies (especially meteorological studies) and statistical data analysis using the special advanced statistical package SAS (Statistical Analysis System).

4. Project Results and Accomplishments

The major result of this study has been the acquisition, selection, application and development of air pollution modeling techniques for the simulation of both short-term (episodes) and long-term (climatological) scenarios. Such simulations provide an important preliminary planning tool to SIA decision-makers.

Two computer models (PTMAX and PTMTP) have been installed in the EPC computer. Using these models the EPC staff are now capable of quickly and independently investigating the consequences of a change in stack height or emission rate upon the maximum ground-level concentration. Four other computer models (ISCST, ISCLT, CDM, and MC-LAGPAR) are available on the KISR computer that allow the running of diffusion simulations and predictions for averaging periods ranging from one hour to one year.

The project team selected several days from the six-year period (1977-82) as being typical of the worst different case atmospheric stability conditions experienced in Kuwait. By using the meteorological data from these days (which are available on the KISR computer) EPC is now able to simulate hourly variations in the most dangerous atmospheric dispersion conditions that can affect Shuaiba emissions.



KIST X 8510

Fig. 3. Annual average ground-level SO_2 concentration isopleths simulated by the ISCLT model. Concentration values are in $\mu g/m^3$ and the UTM coordinates are displayed.

In addition to this major accomplishment, the following three important outputs have been provided by the project:

1. The computerized compilation of important environmental data (meteorological, air quality, emission), their efficient organization in the KISR computer, and their analysis. Particularly important was the compilation of six years of meteorological data from the KWI and the computerized emission inventory for the SIA, which updates the previous estimates of Cremer and Warner (1975).
2. The performance of the special studies and consultants' reports (Volume III), listed below:
   - "A report on surface winds in Kuwait"
   - "Meteorological instruments and practices at the meteorological observation station of the Kuwait International Airport"
   - "The climate of Kuwait"
   - "Preliminary analysis of wind and stability patterns in Kuwait"
   - "Stack sampling; summary of instrument and methods"
   - "Meteorological and air quality computer and data files"
   - "A preliminary collection of atmospheric emission data in the Shuaiba Industrial Area"
   - "Final Report, Scientific Consultancy Service", on source sampling and SIA emission evaluation
   - "Comments concerning air pollution programs in Kuwait", a consultant's report
   - "Land and sea breezes in Kuwait"
   - "A prototype data base management system for meteorological and air quality data"
   - "Tethersonde Balloon description and experiments in Shuaiba"
3. The continuous exchange of technical information between KISR and SAA personnel and the training of SAA staff in using the tethersonde instrumentation, performing source sampling activity, and, especially, using computer diffusion models.

5. Conclusion and Recommendations

The bases of the proper development of SAA-KISR air pollution studies have been successfully built and, based on existing competence, qualifications and knowledge, the next phases of this study can be properly planned.

The following SAA activities can benefit from project results:

- The planning of future industrial development, which, for example, could be approved only in those areas providing the minimum long-term concentration impact.
- The determination of industrial emission standards, to insure compliance with ambient air quality standards.
- The simulation of possible accidental releases, to properly help in designing evacuation plans, intervention strategies, security rules, etc.
- The definition of least-cost emission reduction strategies, in which, if an air quality goal must be achieved, the most cost-effective emission reduction strategy can be identified.
- The identification of major contributors to areas of high air pollution levels around the SIA.

This project has identified the following future needs to fully meet the final SAA objectives mentioned in Section 1.

- Routine computerized data collection, for which the new automatic stations being installed by the SAA/EPC should provide sufficient information.
- Special intensive data collection campaigns, for (1) a complete source sampling of industrial emissions, (2) the performance of additional tethersonde measurements, and (3) the evaluation of the local dispersion rates in the SIA through tracer dispersion experiments.
- Full modeling calibration/evaluation using suitable new air quality measurements in the SIA and special tracer studies.
- Development of *ad hoc* models for the SIA, since available modeling

techniques can be expected to show their limitations in the future when more detailed information on the complex diffusion conditions in Shuaiba will be available.

In conclusion, this study addresses and solves initial problems and identifies the need for further work. KISR recommends the continuation (see Fig. 4) of this project, which has represented an important SAA-KISR collaboration in an extremely relevant area for both SAA and the country of Kuwait. To this end, the scope of work of the Phase 2 study has been enclosed in Section 10 of Volume II for SAA consideration and evaluation.

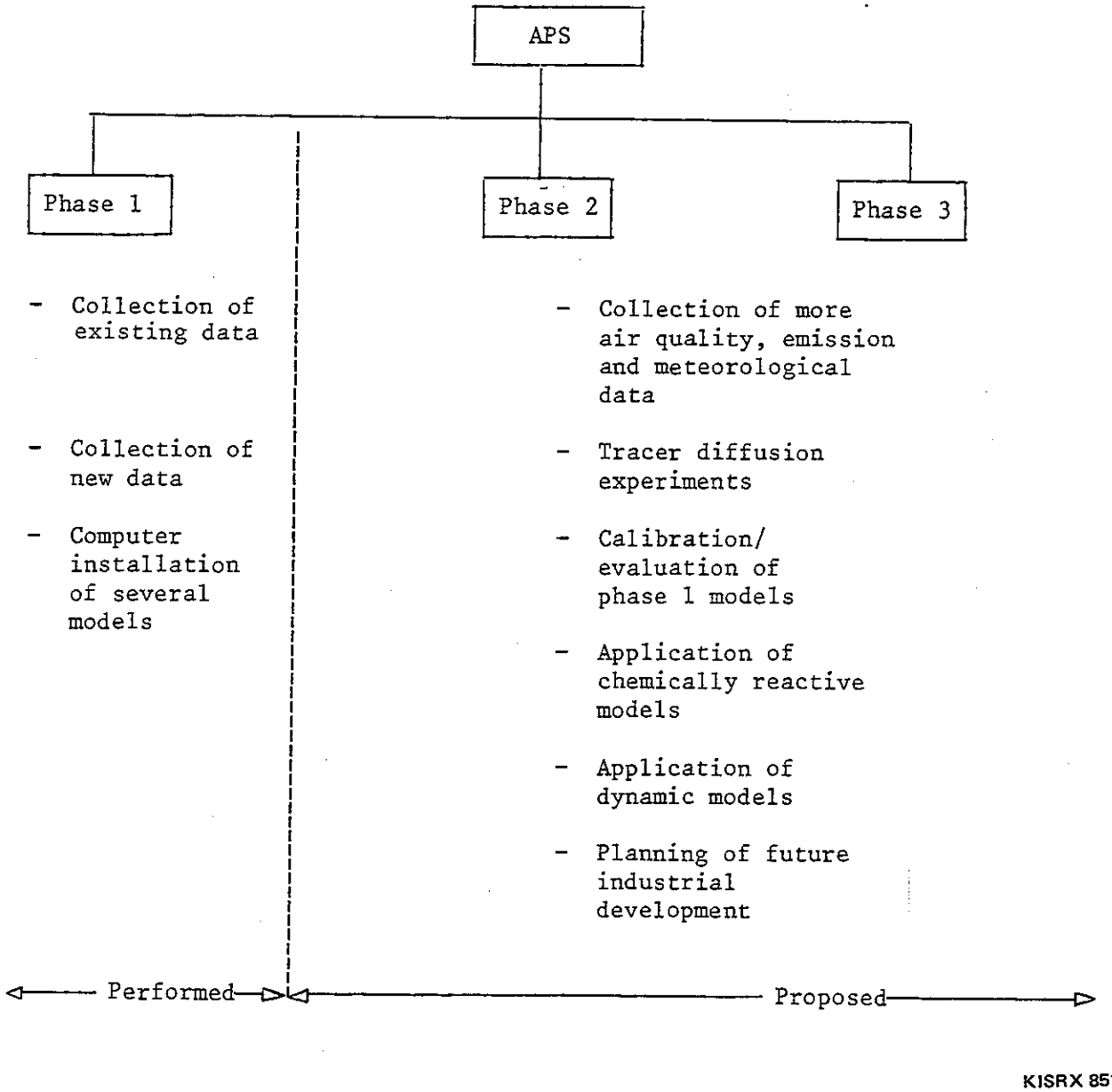


Fig. 4. KISR recommendation for the continuation of the Air Pollution Study (APS).

References

Cremer and Warner, 1975. Air Pollution Control Project. Final report to the Shuaiba Area Authority, Kuwait.

Zennetti, p. 1982. Air pollution dispersion and prediction model for Shuaiba Industrial Area (EES-45). KISR 562, Kuwait Institute for Scientific Research, Kuwait.

KISR

DISTRIBUTION LIST

Check Appropriate Security Classification

DISTRIBUTION : KISR	NUMBER OF COPIES				COPY NOS.
	GENERAL	RESTRICTED	CONFIDENTIAL	OTHER	
Director General	1	1	1		1
DDG/Research	1	1	1 COPY TO APPLICABLE DDG ONLY		2
DDG/Research	1	1			3
DDG/Planning & Development	1	1			
DDG/AF & SS	1	1			
Senior Advisors' Office	1	1			4
Policy and Planning Director	1	1			5
Division Director	5	1	1		6
Department Manager	5	1			7
Project Leader	5	1			8
NSTIC	2	2	1*		9-10
Project Management Office	1	Original + 1	Original + 1		11
Publications & Public Information	Original				
Board of Trustees	13*				
Finance Division	1**	1**	1**		
DISTRIBUTION: OUTSIDE KISR					
Kuwait University	5*				
Client SAA		3			12-14

** Reports only*

*** Proposals and Extensions/Amendments only*

0079 R6/82

Kuwait Institute for Scientific Research
P. O. Box 1638, Salmiya
State of Kuwait