PN-ABI-792

ARAB REPUBLIC OF EGYPT
NATIONAL ORGANIZATION FOR
POTABLE WATER AND
SANITARY DRAINAGE
(NOPWASD)

CANAL CITIES WATER AND WASTEWATER PHASE II PROJECT

USAID CONTRACT 263-0174

FINAL ENVIRONMENTAL ASSESSMENT FOR THE CITY OF SUEZ WASTEWATER TREATMENT PLANT

20 AUGUST 1990

BLACK & VEATCH INTERNATIONAL
ENGINEERS-ARCHITECTS

JMM James M. Montgomery
Consulting Engineers Inc

in association with

SABBOUR ASSOCIATES

PORT SAID ISMAILIA SUEZ

TABLE OF CONTENTS

ACRONYMS AND ABBREVIATIONS xii

EXECUTIVE SUMMARY xiii

1.0 INTRODUCTION 1
1.1 Background 1
1.1.1 Phase I 1
1.1.2 Phase II Project Design 2
1.1.3 Current Phase II 3
1.2 Proposed Action 4
1.3 USAID Environmental Procedures 5
1.4 Egyptian Environmental Legislation 6
1.5 International Conventions on Environmental Protection 7

2.0 PROPOSED FACILITIES AND ALTERNATIVES CONSIDERED 12
2.1 Introduction 12
2.2 Wastewater Flow Projection and Plant Capacity 12
2.3 Influent Characteristics 13
2.4 Effluent Requirements 13
2.5 Plant Siting 13
2.6 Wastewater Collection Facilities 16
2.7 Wastewater Treatment Alternatives 16
2.7.1 Rapid Infiltration Land Treatment 16
2.7.2 Conventional Treatment Processes 18
2.7.2.1 Common Facilities 18
2.7.2.2 Deep Shaft Process 20
2.7.2.3 Conventional Activated Sludge (CAS) 22
2.7.2.4 Aerated Lagoons 22
2.7.2.5 Trickling Filters 23
2.7.3 Sludge Handling 26
2.7.3.1 Gravity Thickener 26
2.7.3.2 Stabilization 29
2.7.3.3 Dewatering 29
2.7.3.4 Storage and Disposal 29
2.7.4 Analysis of Wastewater Treatment Alternatives 30
2.8 Effluent Disposal Facilities 32
2.9 Other Project Elements 32
2.10 Summary of Recommended Project 32

TABLE OF CONTENTS (cont'd)

3.0 EXISTING ENVIRONMENT 36
3.1 General Geographic Setting 36
3.2 Climatology and Meteorology 39
3.3 Physical Oceanography 43
3.3.1 Tides and Waves 43
3.3.2 Currents and Circulation 45
3.3.3 Water Mass Physical Characteristics 49
3.3.3.1 Temperature 49
3.3.3.2 Salinity 52
3.3.3.3 Water Clarity 52
3.3.4 Gulf of Suez 54
3.4 Water Quality 54
3.4.1 Pollutant Sources 54
3.4.1.1 Point Sources 55
3.4.1.2 Nonpoint Sources 55
3.4.2 El Saal Drain 57
3.4.3 Suez Bay 57
3.4.3.1 Dissolved Oxygen 60
3.4.3.2 Biochemical Oxygen Demand (BOD) 60
3.4.3.3 Nitrogen and Phosphorus 61
3.4.3.5 pH 62
3.4.3.6 Chlorophyll a 62
3.4.3.7 Microbiology 62
3.4.3.8 Petroleum Hydrocarbons 63
3.4.4 Gulf of Suez 63
3.5 Marine Resources 65
3.5.1 Phytoplankton 65
3.5.2 Zooplankton 65
3.5.3 Benthic Fauna 66
3.5.4 Fish 66
3.5.5 Marine Turtles and Mammals 68
3.5.6 Marine and Aquatic Birds 68
3.6 Geology and Soils 70
3.6.1 Site 70
3.6.2 Regional and Site Geology 72
3.6.3 Marine Geology 73
3.7 Groundwater 74
3.8 Terrestrial and Aquatic Resources 77
3.8.1 Plant Communities 77

TABLE OF CONTENTS (cont'd)

3.8.2 Wildlife 78
3.8.2.1 Reptiles and Amphibians 78
3.8.2.2 Mammals 79
3.8.2.3 Birds 79
3.8.3 Endangered Species 82
3.9 Land Use and Services 83
3.9.1 General 83
3.9.2 Existing and Proposed Wastewater Treatment Plant Sites 87
3.9.3 Suez Offsite Facilities 88
3.9.4 Demography 89
3.9.5 Water Use and Wastewater Flow 90
3.10 Energy 97
3.11 Air Quality 98
3.12 Archaeological Sites 99

4.0 ENVIRONMENTAL EFFECTS OF THE PREFERRED ALTERNATIVES 100
4.1 Climate and Meteorology 100
4.2 Physical Oceanography 100
4.3 Water Quality 101
4.3.1 Construction Impacts 101
4.3.2 Operational Impacts 101
4.3.2.1 Wastewater Plume Dispersion 102
4.3.2.2 Microbiological Contamination of Recreational Beaches 103
4.3.2.3 Toxic Materials 105
4.3.2.4 Nutrients and Dissolved Oxygen 109
4.3.2.5 Summary of Water Quality Impacts 110
4.4 Marine Resources 110
4.5 Terrestrial Resources 113
4.5.1 Loss of Existing Habitat 113
4.5.2 Creation of New Habitat 113
4.5.2.1 Possible Adverse Impacts 114
4.5.2.2 Beneficial Impacts 116
4.5.3 The Fate and Quality of Effluent 116
4.6 Geology and Soils 117
4.6.1 Terrestrial Geology 117
4.6.2 Marine Geology 117
4.7 Groundwater 118
4.8 Land Use 118
4.8.1 General 118
4.8.2 Existing Treatment Plant Site 119

TABLE OF CONTENTS (cont'd)

4.8.3 Proposed Treatment Plant Site 120
4.8.4 Sludge Disposal 121
4.8.5 Force Main Corridors 122
4.8.6 Wastewater Flow Projection 123
4.9 Public Health Issues 124
4.9.1 Microbiological Water Quality Measurement and Criteria 125
4.9.2 Community Health Concerns 125
4.9.3 Pathogen Removal in Wastewater Treatment 132
4.9.4 Health Impact of Recreational Water Uses 135
4.9.5 Health Impacts with Respect to Fishing and Shellfishing 135
4.9.6 Health Impacts to Wastewater Treatment Plant Operators . . . 135
4.9.7 Health Impacts to Nearby Residents 136
4.9.8 Health Impacts Related to Sludge Handling and Disposal . . . 136
4.9.9 Evaluation of Potential Disease Vectors and Nuisances 137
4.9.10 Health Impacts of Chemicals and Toxic Materials 141
4.9.11 Summary 142
4.10 Energy 142
4.10.1 Energy Consumption 142
4.10.2 Cost-Effectiveness 143
4.11 Air Quality, Noise, Odors 147
4.11.1 Construction 147
4.11.2 Operations 148
4.12 Cultural Resources 148
4.13 Irreversible and Irretrievable Commitments of Resources 149

5.0 ENVIRONMENTAL EFFECTS OF ALTERNATIVES TO THE PROPOSED PROJECT 150
5.1 Treatment Alternative 150
5.1.1 Site Selection 150
5.1.2 Trickling Filter 150
5.1.2.1 Impact on Waterfowl and Migrating Birds 151
5.1.2.2 Energy Consumption 151
5.1.2.3 Operational Reliability 151
5.1.2.4 Water Quality Impacts 152
5.1.3 Conventional Activated Sludge 152
5.1.3.1 Impact on Waterfowl and Migrating Birds 153
5.1.3.2 Operational Reliability 153
5.1.3.3 Sludge Management 153
5.1.3.4 Energy Consumption 154
5.1.3.5 Water Quality Impacts 154
5.1.4 Other Alternatives 154
5.1.5 Sludge Drying 155

TABLE OF CONTENTS (cont'd)

5.2 Effluent Disposal Alternatives 156
5.2.1 Gulf of Suez 156
5.2.2 5-Meter Deep Outfall 156
5.2.3 El Saal Drain 156
5.2.4 Effluent Reuse Alternatives 157
5.2.4.1 Agricultural Use 158
5.2.4.2 Health Considerations 159
5.2.4.3 Wastewater Chemical Composition 162
5.2.4.4 Environmental Effects 163
5.3 Sludge Disposal Alternatives 165
5.4 Disinfection Alternatives 165
5.4.1 Chlorination 166
5.4.2 Dechlorination 167
5.4.3 Other Disinfection Techniques 167

6.0 ENVIRONMENTAL EFFECTS OF THE NO-ACTION ALTERNATIVE . . 169
6.1 Water Quality 169
6.2 Marine Resources 170
6.3 Terrestrial Resources 172
6.4 Geology and Soils 174
6.5 Groundwater 174
6.6 Land Use and Services 174
6.6.1 General 174
6.6.2 Present and Proposed Wastewater Treatment Plant Sites 175
6.6.3 Demography 176
6.6.4 Water Use and Wastewater Flow 176
6.7 Public Health 176
6.8 Energy 178
6.9 Air Quality, Odors, and Noise 178
6.10 Cultural Resources 178

7.0 MITIGATION MEASURES 180
7.1 Marine Water Quality 181
7.1.1 Dispersion and Dilution of the Effluent 181
7.1.2 Effluent Quality 182
7.1.3 Algal Growth and Effluent Quality 182
7.2 Marine Resources 184
7.3 Terrestrial and Aquatic Resources 185
7.4 Land Use 186
7.4.1 Flash Floods and Adjacent Land Uses 186
7.4.2 Existing WWTP Site and Adjacent Land Uses 186

TABLE OF CONTENTS (cont'd)

7.5 Public Health 187
7.5.1 Parasite Removal 187
7.5.2 Worker Safety 188
7.5.3 Sludge Reuse 188
7.6 Energy 189
7.7 Cultural Resources 190
7.8 Geology and Soils 190

REFERENCES 191

LIST OF PERSONS CONTACTED 202

LIST OF PREPARERS 206

APPENDIX A - SCOPING REPORT

APPENDIX B - CANAL CITIES TECHNICAL REPORT: WATER QUALITY ANALYSES - SUEZ

APPENDIX C - FAUNA OF THE SUEZ AREA

APPENDIX D - CONSIDERATIONS FOR AGRICULTURAL REUSE OF EFFLUENT AT SUEZ

LIST OF TABLES

		PAGE
1-1	Law 48 Wastewater Effluent Specifications	9
1-2	Decree 9 (Law 93/1962) Standards for Liquid Wastes	10
2-1	Canal Cities Wastewater Composition (mg/liter)	14
2-2	Required primary and common facilities	21
2-3	Required facilities for aerated lagoons	25
2-4	Preliminary evaluation of sludge treatment alternatives	27
2-5	Comparison of Wastewater Treatment Systems	31
2-6	Costs of Other Project Elements	33
2-7	Summary of Project Costs (US $1,000,000)	35
3-1	Area and Volume of Suez Bay	38
3-2	Pollutant Discharge to Suez Bay, 1970	56
3-3	Chemical Characteristics of Raw Sewage in Suez	58
3-4	Chemical Characteristics of Water Samples from El Saal Drain	59
3-5	Fish families represented in the samples of the Soviet expedition (1964-1965)	67
3-6	Common and scientific names for turtles and marine mammals known to inhabit the Gulf of Suez region	69
3-7	Summary of four wader counts at the intertidal mudflats of Suez Bay	71
3-8	Results of groundwater sample analysis	76
3-9	Summary of birds of prey counts at Suez	81

LIST OF TABLES (cont'd)

		PAGE
3-10	Population of the Governorate of Suez 1976-1986	85
3-11	Suez City "High" and "Low" Population Projections for 1986-2015	91
3-12	Monthly Water Supply from Suez Potable Water Treatment Plant July 1988 - June 1989	92
3-13	Suez City: Water Use by User Type 1988-1989	93
3-14	Suez City: Water Use by the Government and Public Sector 1988-1989	94
3-15	Suez City: Water Use by District 1988-1989	95
3-16	Suez City Water Use by Selected Industries 1987-88	96
4-1	Heavy metal removal rates	106
4-2	Expected Metals Discharge to Suez Bay	108
4-3	Microbiological Quality of Water Guidelines/Standards (per 100 ml)	126
4-4	Viral, Bacterial and Protozoan Pathogens in Wastewater	127
4-5	Helminthic pathogens excreted in feces	128
4-6	Relative health risks from use of untreated excreta and wastewater in agriculture and aquaculture	131
4-7	Summary of Pathogen Removal by Various Sewage Treatment Processes	133
4-8	Survival times of selected excreted pathogens in soil on crop surfaces at 20-30°C	138
4-9	Parasite Concentrations in Different Sludges at Alexandria, Egypt	139

LIST OF TABLES (cont'd)

PAGE

4-10 Parasite Concentrations in Dry and Composted Sludge, Alexandria, Egypt 140

5-1 Recommended microbiological quality guidelines for wastewater use in agriculture 161

5-2 Recommended Maximum Concentration of Trace Element and Heavy Metal Ions in Irrigation Water, and Concentrations in Suez City Wastewater Influent 164

LIST OF FIGURES

		PAGE
1-1	Regional Location Map, Canal Cities Project	2
2-1	Suez Area	15
2-2	Suez, Schematic-Existing Pump Stations and Force Mains	17
2-3	Proposed Wastewater Collection Facilities	19
2-4	Aerated Lagoon Plant Layout	24
2-5	Proposed Sludge Process Trains, Suez	28
3-1	Map of Suez Bay	37
3-2	Monthly and Annual Wind Roses for Suez, 1965-1972	40
3-3	Cumulative Percent Frequency of Occurrence Wind Speed (Knots) At Suez By Month 1965-1972	41
3-4	Climatic Conditions at Suez, Egypt	42
3-5	Mean Monthly Sea Level at Port Tewfiq	44
3-6	Current Meter Records From Station 5, Off El Saal Drain November - December 1989	46
3-7	Current Rose for Station 5, Off El Saal Drain November - December 1989	47
3-8	Progressive Vector Diagram for Current at Station 5, off El Saal Drain November - December 1989	48
3-9	Current Profile Data from Station 6, near Proposed Submarine Outfall November - December 1989	50
3-10	Annual Variation in Monthly Air and Seawater Temperatures at Suez, Egypt	51

LIST OF FIGURES (cont'd)

		PAGE
3-11	Average Salinity, Temperature, and Dissolved Oxygen in Suez Bay 1966-1967	53
3-12	Distribution of Amoebic Cysts	64
3-13	Groundwater Sampling Sites	75
3-14	Existing and Proposed Land Use	86
4-1	Minimal Infective Dose of Enteric Pathogens-Clinical Response of Adult Humans to Varying Challenge Doses	130
4-2	Present Worth Comparison with Varying Cost of Electrical Power	146

ACRONYMS AND ABBREVIATIONS

ARE	-	Arab Republic of Egypt
BOD	-	Biochemical oxygen demand
BOD_5	-	5-day biochemical oxygen demand
cm	-	centimeter
cm/sec	-	centimeter per second
°C	-	degrees Celsius
CEQ	-	Council of Environmental Quality
CFR	-	Code of Federal Regulations
CMC	-	Construction Management Consultants
COD	-	Chemical oxygen demand
DO	-	Dissolved oxygen
EA	-	Environmental Assessment
EPA	-	United States Environmental Protection Agency
°F	-	degress Farenheit
GOPP	-	General Organization for Physical Planning
km	-	kilometer
LE	-	Egyptian pounds (currency)
l/day	-	liters per day
m	-	meter
m^2	-	square meter
m^3/d	-	cubic meter per day
mg/l	-	milligram per liter (concentration)
m/sec	-	meters per second
mm	-	millimeter
NOPWASD	-	National Organization for Potable Water and Sanitary Drainage
ppt	-	parts per thousand (concentration)
SCA	-	Suez Canal Authority
sm^3	-	standard cubic meter (volume of air at standard pressure and temperature)
TDS	-	total dissolved solids
TSS	-	total suspended solids
ug/l	-	micrograms per liter
UNEP	-	United Nations Environmental Programme
USAID	-	United States Agency for International Development
US$	-	United States dollars (currency)
WHO	-	World Health Organization
WWTP	-	wastewater treatment plant

ENVIRONMENTAL ASSESSMENT OF A NEW WASTEWATER TREATMENT PLANT PROPOSED FOR SUEZ

EXECUTIVE SUMMARY

1.0 INTRODUCTION

1.1 Background

Egypt's National Organization for Potable Water and Sanitary Drainage (NOPWASD), in association with the U.S. Agency for International Development (USAID), is proposing to build a new sewage treatment plant for Suez. The proposed treatment plant is one element of Phase II of the Canal Cities Water and Wastewater Project, which is partially funded by USAID.

Over 10 years of planning effort have gone into developing a preliminary design for wastewater treatment facilities at Suez that would be both cost effective and environmentally sound. During this period, the recommended treatment and disposal concept changed from:

- o secondary treatment with oxidation ponds, followed by disposal of the effluent to Suez Bay; to
- o two primary treatment plants, one in the north whose effluent would be used for irrigation, and one in the south with discharge to Suez Bay; to
- o anaerobic lagoon treatment and land disposal by rapid infiltration; and most recently to
- o aerated lagoon treatment with discharge to Suez Bay.

1.2 Proposed Action

NOPWASD and USAID have agreed that an aerated lagoon treatment method should be used by the proposed Suez wastewater treatment plant, basing their decision on considerations of cost, simplicity of operation, land requirements, and effluent

quality. The treatment plant will be located on the west shore of Suez Bay in an industrial zone about 4 km southwest of the existing facility, and it will discharge treated effluent to Suez Bay. The proposed action will vastly improve the quality of wastewater now flowing virtually untreated into Suez Bay from Suez.

NOPWASD, in association with USAID, is conducting this Environmental Assessment (EA) of the proposed new sewage treatment plant for Suez. This document intends to inform NOPWASD and USAID decision-makers, as well as other concerned parties, about existing environmental conditions, potential environmental impacts of the proposed project's construction and operation, possible mitigating measures, monitoring programs, and opportunities for environmental enhancement. The EA is being prepared in accordance with USAID environmental procedures. Final USAID authorization of construction funding depends on approval of the EA.

1.3 Environmental Legislation

The two major Egyptian environmental laws affecting wastewater discharges and water quality are Law 48/1982 and Law 93/1962. Law 48 is focused on protecting fresh water resources that are required for both potable and non-potable/agricultural use. Law 93 sets standards and specifications required for liquid wastes to be discharged into public sewerage networks, surface drainage systems, and to irrigate cultivated lands. Law 93 also requires a permit from the Ministry of Health for effluent discharge before a wastewater treatment plant can be built.

Egypt is a signatory to the Red Sea and Gulf of Aden Action Plan administered by the UNEP Regional Seas Programme. The UNEP Red Sea Action Plan clearly defines the area to be included as the Red Sea, the Gulf of Aqaba, the Gulf of Suez, and the Suez Canal to its connection with the Mediterranean Sea. This program is designed to prevent discharges of oil, toxic wastes and other forms of ocean dumping. Additional protocols related to controlling pollution from land-based sources (e.g., sewage treatment plants) have not yet been developed, although guidelines for submarine outfalls have been drafted for a similar UNEP Action Plan for the Mediterranean.

2.0 FACILITIES AND ALTERNATIVES CONSIDERED

The planning and design horizon for the project has been redefined from the year 2000 to the year 2005. Anticipated wastewater flows at Suez in 2005 will be 130,000 m^3/d, with 86% of the population served.

Alternative treatment and disposal methods that have been considered in detail in recent analyses include:

- primary treatment with land disposal via rapid infiltration beds;
- aerated lagoon treatment with disposal to Suez Bay or the Gulf of Suez;
- trickling filter treatment with disposal to Suez Bay or the Gulf of Suez;
- deep shaft treatment with disposal to Suez Bay or the Gulf of Suez; and
- conventional activated sludge treatment with disposal to Suez Bay or the Gulf of Suez.

Primary treatment with land disposal via rapid infiltration beds was eliminated from further consideration as an alternative because the land previously thought to be available was no longer available. No other suitable sites of sufficient size could be identified within a distance that was economically feasible.

Key factors used in evaluating the technical and economic features of the remaining treatment alternatives are identified in Table S-1 along with their relative rankings. The deep shaft treatment process was eliminated from further consideration as an alternative due to its high cost relative to the remaining treatment methods.

The preferred alternative has been identified as an aerated lagoon treatment system at a site located on the west shore of Suez Bay, with disposal to Suez Bay via an outfall located offshore at the 10-m isobath. The system comprises a series of complete mix aerated lagoons, partial mix aerated lagoons, and polishing ponds. Sludge will be periodically removed from the lagoons, dried in dedicated lagoons, then deposited in a quarry located on the western edge of the proposed treatment plant site.

Selection of the aerated lagoon treatment system was based on its superior ranking with respect to low capital costs, high reliability, and simple operation (Chapter 2). Particularly important in its selection was its ability to provide at least some treatment even if the aeration system, the key component of the treatment plant, was inoperable for more than 1-2 weeks. The remaining economically feasible treatment systems quickly become non-functional if the key treatment process becomes inoperable (Chapter 5). Present worth costs of the aerated lagoon system were deemed comparable to other conventional treatment methods, although energy costs for operation were the highest of the conventional treatment alternatives considered (Chapter 4).

3.0 ENVIRONMENTAL IMPACTS

Impacts of the preferred alternative on water quality, marine resources, terrestrial and aquatic biota, geology and soils, groundwater, land use, public health, energy, air quality, and cultural resources were evaluated in Chapter 4 of this EA.

Table S-1. Comparison of Wastewater Treatment Systems.

Treatment Alternative	Capital[1] Cost (10^6)	Annual O&M Costs (10^6)	Present Worth Value (10^6)	Reliability	Ease of Operation	Maintenance	Sludge Mgmt	Land Requirement
Aerated Lagoons	$ 75.00	$ 1.60	$ 77.89	High; will provide treatment even without aerator	Simplest	Low; aeration systems can fail	Simplest	Most[b]
Trickling Filters	86.90	0.99	83.77	Moderate; will withstand 24-hr shut down	Simple; familiar to Egyptians	Moderate susceptible to sedimentation	Stabilization required	Moderate
Deep Shaft without Primary Clarifiers	98.28	1.25	95.57	Low; sensitive to proper operation	Complex;	High	Stabilization required	Least
Conventional Activated Sludge without Primary Clarifiers	87.30	1.32	86.24	Low; sensitive to proper operation	Complex; sensitive to loading shocks and perturbations	High	Stabilization required	Moderate

a: Total cost for treatment alternative and sludge facilities.

b: After elimination of rapid infiltration.

Impacts of the other alternatives were analyzed in Chapters 5 and 6. Table S-2 summarizes the key findings of these analyses.

Potentially significant adverse impacts that may result from the proposed action have been identified in Chapter 4. These include:

- o impacts of the wastewater plume on the seawater intake proposed for the Institute of Oceanography and Fisheries research station; and
- o effects on nearby land uses if flash floods impact the sludge disposal site and treatment plant.

In addition, Chapters 4 and 5 note the following factors that may be considered in improving environmental soundness of the project, although significant adverse environmental effects are not anticipated at this time:

- o use of the lagoons by migrating birds and possible problems associated with birds contacting sludge drying lagoons and power lines;
- o effects of effluent and sludge disposal on human health;
- o use of the existing wastewater treatment plant and its site, and compatibility with surrounding land uses; and
- o operational energy consumption.

These issues are briefly summarized in this section of the Executive Summary, and appropriate mitigation measures are briefly summarized in Section 4 of the Executive Summary.

3.1 Water Quality at Fisheries Research Station Intake

The overall impact of the proposed action is to improve water quality in Suez Bay; the discharge of raw sewage will cease. Preliminary analyses suggest that the wastewater plume from the proposed outfall occasionally may be blown by east winds toward the fisheries research station. If the research station eventually puts a seawater intake within a few hundred meters offshore of its facility, particulates settling from the wastewater plume could adversely affect the quality of water in the intake during periods of east wind. Although east winds are not common and the amount of suspended matter entering the intake may not be large, a potential exists for disrupting research that is sensitive to water quality.

Table S-2. Environmental Consequences of Treatment Alternatives with Disposal to El Mahsama Drain.

Treatment Alternative	Water Quality	Marine Resources	Terrestrial & Aquatic Biota	Geology & Soils	Groundwater	Land Use	Public Health	Energy	Air Quality	Cultural Resources
Aerated Lagoons	Acceptable	Localized impact around outfall; insig.	Small risk of adverse impact on migrating birds	Insig.	Insig.	Minor; potential impact on fisheries station	Minor; insig.	Highest energy use	Nuisance to graphite factory; minor	Minor
Trickling Filters	Acceptable if operated properly	Localized impact around outfall; insig	Small risk	Insig.	Insig.	Minor; potential impact on fisheries station	Minor; insig.	Low energy use	Greater nuisance from sludge stabilization	Minor
Conventional Activated Sludge	Acceptable if operated properly; most susceptible to operating conditions	Localized impact around outfall; insig.	Small risk	Insig.	Insig.	Minor; potential impact on fisheries station	Minor; insig.	Moderate energy use	Greater nuisance from sludge stabilization	Minor
No-Action	Unacceptable	Localized impact around El Saal Drain; adverse	No impact, or deferred	Insig.	Insig.	Sign. adverse impact near existing WWTP and El Saal Drain	Adverse impact near El Saal Drain; potentially sign.	Least energy use	Adverse around existing WWTP and El Saal Drain; significant.	None

Note: insig. = insignificant impact

3.1.1 Impact of Aerated Lagoons

Aerated lagoon systems are least susceptible to fluctuations in wastewater load. If for some technical or fiscal reason the aeration system does not operate for more than 1-2 weeks, the preferred alternative will continue to provide a reduced level of treatment to the wastewater. The preferred alternative provides most reliable protection of water quality, and therefore offers the least risk to the fisheries research station's proposed seawater intake.

3.1.2 Impact of Trickling Filters

Impacts of the trickling filter system on the fisheries research station's seawater intake are essentially comparable to that of the aerated lagoon system, with one important exception. If the trickling filters were inoperable for a period less than 24 hrs, the treatment process would not suffer dramatically. If the trickling filters were inoperable for a longer period of time, effluent quality would be significantly reduced. Trickling filters pose a slightly greater risk to water quality at the fisheries research station's seawater intake.

3.1.3 Impacts of Conventional Activated Sludge

Under normal operating conditions, the impacts will be comparable to that of the aerated lagoon and the trickling filter system.

The activated sludge system is most susceptible to changes in wastewater load and operational changes. It does not take a large perturbation in operational conditions to significantly change the performance of the treatment system, and the system is most demanding of well trained staff and performance monitoring. If the system becomes inoperational, essentially untreated wastewater will be discharged very soon thereafter. This system offers the greatest risk to the fisheries research station's seawater intake.

3.2 Land Use

Impacts of the three treatment alternatives that were analyzed are comparable.

If appropriate berms and dikes are not constructed at the boundaries of the property, flash floods could course through the sludge disposal site and the wastewater lagoons and carry wastes into the neighboring properties and Suez Bay. Design of such flood prevention structures must not only consider protection of the sludge disposal site

and wastewater treatment plant facilities, but also avoid diverting flood flows into neighboring facilities.

Construction of the new treatment plant will make the existing treatment plant available for other uses. The proposed project does not provide for use of the existing treatment plant. At present, the Governorate proposes to partially treat a fraction of the wastewater flow at the existing site, and deliver it for further treatment to the new treatment plant. This potentially is incompatible with plans to expand housing and park facilities on adjacent properties. Nuisance conditions caused by odors and flies are likely to continue in the vicinity of the existing treatment plant.

3.3 Terrestrial and Aquatic Resources

3.3.1 Impact of Aerated Lagoons

The lagoons are likely to attract migrating waterfowl, especially storks, and other birds that use aquatic habitats. These, in turn, will attract some of the migrating raptors (predatory birds). The sludge drying lagoons at Sharm El Sheikh have trapped and led to the deaths of a significant number of storks during the fall migration. Floating solid wastes (e.g., plastic bags) in the lagoons at Sharm El Sheikh have occasionally been ingested by birds and led to suffocation or starvation and death. Similar effects are not expected to take place at the proposed treatment plant in Suez when storks are migrating in the spring through the Suez area, because of significant differences in design and operation of the proposed Suez treatment plant and in oil and grease content of the sewage. Monitoring, however, is required to verify this conclusion.

Overhead power lines are often used as perch sites by raptors. Accidental short-circuiting and death of these birds may occur on occasion, especially with typical design of lower voltage distribution lines. Power lines also pose a collision hazard for birds during periods of low visibility due to fog, dust, or poor air quality.

3.3.2 Impact of Trickling Filters

A trickling filter system will entail significantly less area of open water than the aerated lagoon system. Thus, the attraction of this system to migrating waterfowl will be less than that of an aerated lagoon system. Furthermore, moving booms over the trickling filters will tend to discourage resting by migratory waterfowl. It must be noted, however, that the sources of the potential threat to migratory birds, i.e., powerlines and sludge drying lagoons, remain. The primary difference between the two alternatives is the presumed degree of attraction offered by differences in surface area of open water.

3.3.3 Impact of Conventional Activated Sludge

An activated sludge treatment system will include significantly less open water surface area than would aerated lagoons. Thus, the discussion noted for trickling filters and their reduced ability to attract migrating birds also applies to an activated sludge treatment plant.

3.4 Public Health

3.4.1 Impact of Aerated Lagoons

Although the treatment process will significantly reduce the presence of fecal coliform bacteria in the effluent, certain parasites will not be effectively removed by the proposed aerated lagoon operational plan. This is of minor significance with marine discharge, unless the wastewater plume is carried to known recreational beaches or if effluent is used in the future for irrigation.

Workers at the treatment plant, especially those handling sludge, are at greatest risk to public health problems with pathogens, viruses, and parasites. Poor sanitation practices may result in increases in worker health problems.

3.4.2 Impact of Trickling Filters

A requirement for sludge stabilization increases the risk of exposure of workers by increasing the degree of sludge handling. The trickling filter system is more susceptible to failure. If trickling filters cease operation for more than 24 hrs, virtually untreated wastewater will be discharged, increasing risk of public health problems in the nearshore zone.

3.4.3 Impact of Conventional Activated Sludge

A requirement for sludge thickening and stabilization increases the risk of exposure of workers by increasing sludge handling. This treatment system is most susceptible to failure, increasing the risk of public health problems in the nearshore zone.

3.5 Energy Consumption

3.5.1 Impact of Aerated Lagoons

Differences in energy consumption during operation of the plant are discussed in detail in Chapter 4. Of the treatment alternatives that appear economically to be the most feasible, the aerated lagoon system is the most energy-intensive to operate. One important consideration is that the burden of operational and maintenance (O&M) costs is placed on the Governorate, whereas construction costs are provided at the national level with grant assistance from USAID.

The amount of energy, however, is insignificant in terms of national energy production. A second important consideration is that electricity costs are low significantly subsidized, and the rate of increase to long range marginal costs of generation is not known. Finally, a tariff study is underway, and the data will be used by the Governorate to ameliorate impact of O&M costs. Project Grant Agreements also address O&M funding. Thus, under present conditions, the difference in energy consumption is not clearly a significant adverse impact.

3.5.2 Impact of Trickling Filters

For Suez, estimated annual energy consumption for a trickling filter facility is 33% of that required to operate aerated lagoons. This represents a significant savings in energy consumption, although the significance of this savings in operational cost is unclear under current energy pricing policy.

3.5.3 Impacts of Conventional Activated Sludge

Energy requirements for an activated sludge operation are intermediate between aerated lagoon and trickling filter systems, but still significantly less than the aerated lagoon system. For Suez, a conventional activated sludge system without primary clarifiers would require about 60% of the energy required to operate the proposed aerated lagoon system. This difference would decrease if primary clarifiers were incorporated. The impacts of energy consumption are, therefore, comparable to those described above for trickling filters, but the magnitude of the difference would be less.

4.0 PROPOSED MITIGATION MEASURES

4.1 Water Quality

The potential adverse impacts on water quality in the vicinity of the fisheries research station's future seawater intake may be mitigated or eliminated by selecting a

deeper discharge depth and by designing a diffuser system for maximum dilution. However, outfall location must be a trade-off between the desire to locate as deep and as far from shore as possible as well as avoiding conflict with shipping and underwater cables in Suez Bay. A monitoring program is recommended to examine plume dispersion, effluent quality, and water quality in the area near the proposed seawater intake. Monitoring programs would be included by the design/build contractor in the operations and maintenance manuals and training programs for treatment plant operators.

4.2 Land Use

Measures should be taken to ensure that flash floods do not sweep through the sludge disposal or treatment plant site, and that measures to divert flood flows do not divert these flows to the detriment of adjacent properties. The design/build contractor will conduct flash flood analyses and incorporate appropriate flood protection structures in the final design.

Additional improvement of water quality and use of shoreline habitat by migrating shorebirds in Suez Bay can be achieved with an investigation of industrial waste discharges and design of appropriate treatment of industrial wastes. Such a plan may incorporate the existing wastewater treatment plant, which will be made available for other uses by the proposed action. The Canal Cities project includes an evaluation of industrial wastewater management needs in Suez.

4.3 Migrating Birds

The design/build contractor will incorporate a monitoring program for use of the facilities by migrating birds in the operations and maintenance manuals and training programs for treatment plant operators.

If the proposed monitoring program indicates an unusually or unnecessarily high rate of deaths of birds at the facilities, the entrapment threat to migrating waterfowl offered by sludge drying lagoons may be effectively countered by the use of temporary netting and fencing to prevent birds from landing on or walking into the sludge drying lagoons during migratory season.

Since poor visibility is not a common problem at Suez, collisions between birds and the power lines are not expected to be significant sources of mortality. The risk can be further reduced by placing new power lines underground and locating open water as far as possible from the high voltage power lines currently crossing the site.

Risks of short circuits and electrocution of birds, especially raptors, can be significantly reduced by providing well insulated perch sites atop existing power poles,

erecting taller perching posts nearby, or planting tall-growing trees nearby, which could be watered with treated effluent.

4.4 Public Health

It is recommended that a medical surveillance program be developed to ensure that all treatment plant operators are properly immunized and trained to maintain high levels of personal hygiene. Antihelminthic drugs are available and have proved effective if reinfection can be prevented. Iron supplements can alleviate the anemia of individuals who are suffering from hookworm infections until the exposure to the disease can be reduced. The design/build contractor will include worker health and safety programs in operations and maintenance manuals and in training programs for plant operators.

Laundry facilities for workers' clothing to prevent transmission of pathogens to workers' homes and families should be considered. Provision of protective clothing for workers likely to come into contact with pathogens is recommended. The use of rubber or plastic footwear is recommended, especially for workers handling sludge.

4.5 Energy

A tariff study is underway to assist the Governorate in establishing appropriate user fees and ameliorate increased O&M costs.

Features that might improve energy efficiency or make use of low-cost, low-technology wind or solar power sources should be considered during final project design. Properly sized and energy efficient electrical motors and transformers should be used. The design/build contractor will consider energy efficiency and conservation measures in final design and development of O&M procedures.

4.6 Cultural Resources

If any suspected cultural resources or historical artifacts are uncovered during project construction, all work in the immediate area should be stopped and a qualified archeologist consulted for recommendations. These recommendations should be implemented by the design/build contractor in consultation with Egyptian officials in the Department of Antiquities, Ministry of Culture.

5.0 IMPACTS OF OTHER EFFLUENT DISPOSAL ALTERNATIVES

5.1 Gulf of Suez

Although the Gulf of Suez has better circulation and a higher potential for dilution of sewage effluent, it also is the site of several extremely valuable fisheries. Effluent from the wastewater treatment facility poses a minor risk to some of these fisheries occurring near any proposed outfall, and increases the health risk to those individuals consuming these species. The Gulf of Suez is also an area where tourism is increasing at a high rate. Sewage effluent that contains pathogenic bacteria, viruses, and parasites may pose a serious health threat to those contacting the water during recreational activities. Consequently, the Gulf of Suez is not recommended as the preferred alternative due to the potential adverse impacts on the tourism opportunities and benthic fisheries in the vicinity of the outfall. Extensive fisheries and tourism related activities do not occur in Suez Bay.

5.2 5-Meter Deep Outfall

The 5-m deep outfall does not provide the dilution of heavy metals and other pollutants that is produced by the 10-m deep outfall (Chapter 4). In particular, higher levels of pathogens may be expected along the shoreline during the infrequent event of winds from the east (Chapter 4). There is also concern that this alternative would have a greater risk of adverse impacts on proposed and existing seawater intakes at the fisheries research station and the power plant facilities (Chapter 5). Therefore, the 5-meter outfall is not recommended as the preferred alternative.

5.3 El Saal Drain

Use of the El Saal Drain as the effluent discharge point for the proposed wastewater treatment facility would continue to produce the risk of adverse impacts on public health in the nearshore zone around the mouth of the drain. The dilution and dispersion will be significantly less than that of either the 5-m or 10-m deep outfall. The short-term benefits of improved water quality in the nearshore area will slowly disappear as population and industrialization increases around the city of Suez. Because this alternative offers significantly less benefit to the marine environment, El Saal Drain is not recommended as the preferred alternative.

5.4 Effluent Reuse Alternatives

Treated wastewater can be a valuable resource for irrigation or aquaculture where supplies of fresh and clean potable water are limited. However, a prime consideration is to ensure that the potential for disease transmission is eliminated.

ORGANIC MATTER AND NUTRIENT CONTENT OF DIFFERENT SOIL CONDITIONERS

Soil Conditioner	Percent Weight					
	Moisture Content	Organic Matter	Nitrogen N	Phosphate P	Potassium K	C:N Ratio
Cattle Manure	0.8	36.0	1.7	0.6	1.2	18 : 1
Chicken Manure from egg production	8.6	4.92	1.1	-	-	26 : 1
Chicken Manure from meat production	16.08	86.1	2.5	-	-	20 : 1
Sewage Sludge	43.0	34.0	2-5	1-2	0.2	9-11:1
Peat Moss*	45-50	40-45	-	-	-	-
Municipal Waste Compost	6.5	22-25	1.3	0.8	0.9	18 : 1

* Peat Moss does not normally contain any nutrients but is often enriched with chemical fertilizers up to a rate of 1% nitrogen, 1% phosphate and 1.7% potassium.

Table 9 illustrates the average price of organic fertilizers per cubic meter.

Source: EQI, Dec 1989, p. 13

The alternatives for effluent reuse at Suez are limited by the high salt content of the wastewater (approximately 5000 mg/l). High dilution rates with fresh water would be required before application to agricultural crops, so agricultural reuse is probably not economically feasible.

Aquaculture is a more plausible alternative as the salt content is not a factor. In the event that a suitable aquaculture site could be found, additional treatment for pathogen removal would be recommended. Improvements in removal of helminth (intestinal worm) and parasitic cyst pathogens can be achieved by several methods. After a preliminary review of the benefits and appropriateness of parasite removal technologies, it is recommended that slow or intermittent sand filtration be used if effluent reuse is employed at a future date.

6.0 ALTERNATIVE SLUDGE TREATMENT AND DISPOSAL METHODS

Alternatives to disposal of the sludge on the site include use by farmers for land reclamation and soil amendment, and composting with municipal solid waste.

Use of sludge as a soil amendment appears highly desirable because of a need for more arable land in Egypt. Primary concerns, however, are implications for human health as a result of pathogens and heavy metals in the sludge. Current operational plans do not include reuse of sludge because of public health concerns. If the Egyptian government decides in the future to expand or modify the treatment plant to include sludge reuse, additional treatment to remove pathogens and helminth eggs found in the sludge is recommended before local farmers are permitted to use the sludge as fertilizer or soil conditioner. To reduce the possibility of *Ascaris* egg survival and reinfection, dried sludge should be spread on dedicated land for 6 months to 1 year before allowing local farmers to remove the sludge for their own purposes. Plant operators should periodically test the sludge and document the occurrence and viability of *Ascaris* eggs in this material. Sludge that contains viable eggs should not be used in areas where reinfection can occur.

The need for additional drying and storage would be negated by the use of a composting operation. Sludge tends to be high in nitrogen content but is generally considered a low-grade fertilizer due to other mineral limitations. Garbage has a high organic content and has good bulking qualities. Co-composting of these two materials produces a good, useful product. Composting with municipal solid waste may offer important advantages, but impacts cannot be adequately evaluated without description of a proposed plan. While the provision of composting is considered outside the scope of this project, it is recommended that Suez Governorate evaluate this option in the future in context with its waste management plans to determine if this would be beneficial to Suez.

ENVIRONMENTAL ASSESSMENT OF A NEW WASTEWATER TREATMENT PLANT PROPOSED FOR SUEZ

CHAPTER 1

1.0 INTRODUCTION

1.1 Background

Suez, a city of approximately 281,000 people (1986 census data), is located on the northern shore of Suez Bay, which is located on the northern tip of the Gulf of Suez. The city is the southernmost of three cities that lie along the Suez Canal; the others are Port Said at the northern end of the canal, and Ismailia lying midway between the two (Figure 1-1). Suez is an industrialized city with oil refineries and related petroleum infrastructure. Located at the southern terminus of the Suez Canal, it has extensive port and harbor facilities and is the seat of the Suez Governorate. Suez Bay is a major anchorage for ships waiting to pass through the Suez Canal.

Egypt's National Organization for Potable Water and Sanitary Drainage (NOPWASD), in association with the U.S. Agency for International Development (USAID), is proposing to build a new sewage treatment plant for Suez. Once NOPWASD, a unit of the Ministry of Development, New Communities, Housing and Public Utilities, has built the new plant, it will be operated by the Suez Governorate's Wastewater Department.

1.1.1 Phase I

The proposed treatment plant is one element of Phase II of the Canal Cities Water and Wastewater Project, which is partially funded by USAID. The project's current phase continues more than a decade of effort to rehabilitate the canal cities' war-damaged water and wastewater systems, and to provide capacity for their future growth. The wastewater component of Phase I allayed the immediate critical problems of raw sewage flooding and ponding on city streets by cleaning, repairing, and expanding existing wastewater collection systems, and by constructing several new wastewater pumping stations. Planning for treatment facilities also occurred under Phase I.

USAID's priorities have been that the facilities be cost effective and environmentally sound. The Suez Wastewater Facilities Master Plan (Pirnie-Harris

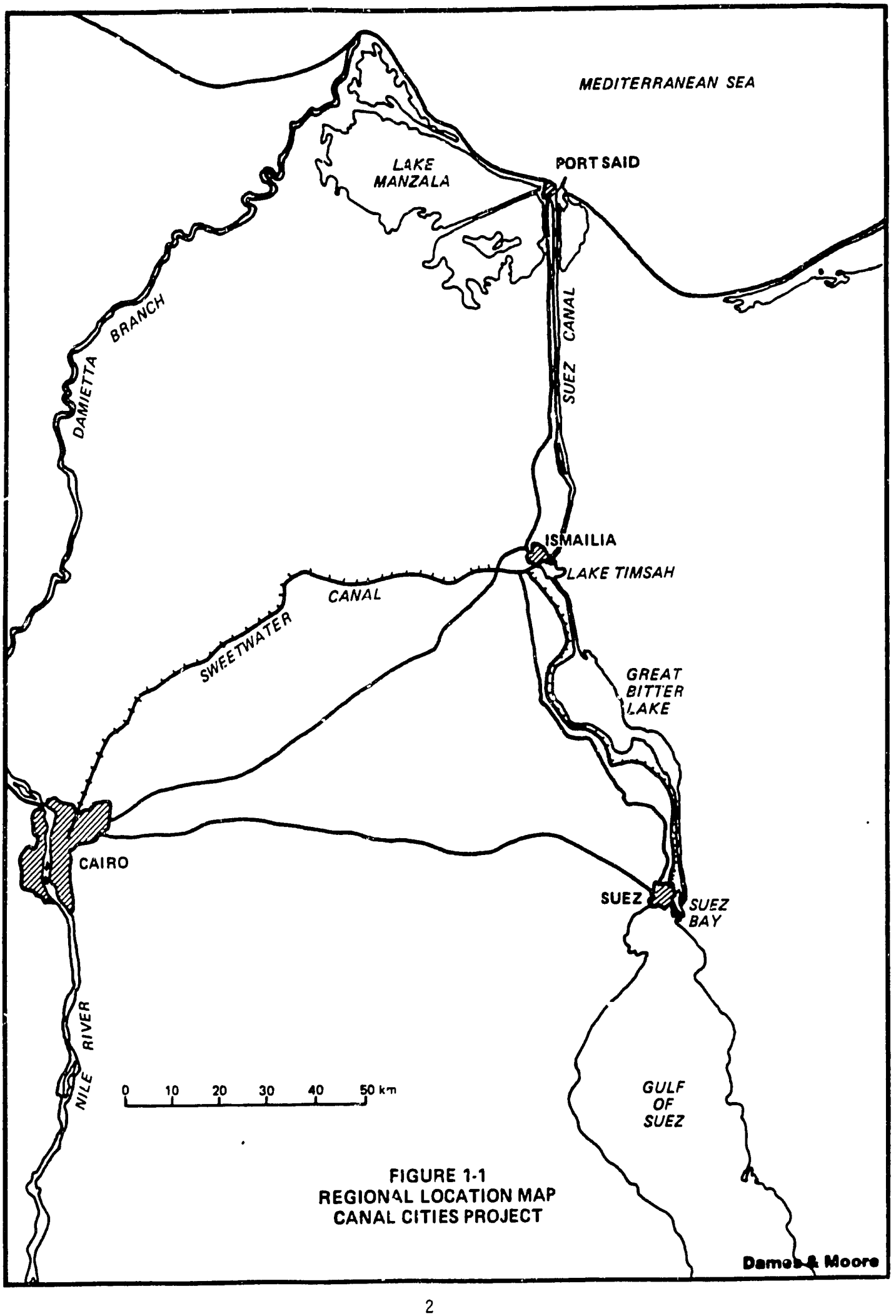


FIGURE 1-1
REGIONAL LOCATION MAP
CANAL CITIES PROJECT

International, 1979) recommended secondary treatment with oxidation ditches and discharge to Suez Bay, or primary treatment with disposal to the Gulf of Suez. The Facilities Master Plan also evaluated several alternative wastewater disposal options. They included: discharging to Suez Bay, the Gulf of Suez, the Suez Canal, or Suez Creek (which empties into the Canal); wastewater reclamation for irrigation, aquaculture, and industrial reuse; evaporation; and subsoil disposal. Wastewater reclamation and reuse alternatives for Suez were not considered feasible by the 1979 Master Plan, primarily due to the wastewater's high total dissolved solids contents. Evaporation and subsoil methods also were judged infeasible due to high groundwater levels and the unavailability of large tracts of land within a reasonable distance of the city. Direct disposal to Suez Creek or to the Suez Canal would have required a very high level of treatment. Such a discharge might have had adverse environmental impacts on Great Bitter Lake due to the predominantly northward flow in this part of the Suez Canal during most of the year.

In order to assess the ability of Suez Bay and the Gulf of Suez to assimilate the wastewater discharge, the 1979 Master Plan included an oceanographic and water sampling program, and a subsequent water quality modeling effort (Marine Environmental Services, 1979). This study recommended that secondary treatment with nitrification would be necessary for a wastewater discharge to Suez Bay due to poor circulation within the Bay area. Alternatively, a discharge of primary-treated wastewater to the Gulf of Suez was judged to be acceptable. It would have a smaller water quality impact than discharging secondary-treated effluent to the Bay. Even though a marine outfall to the Gulf of Suez was considered to be the best solution from an engineering point of view, the 1979 Master Plan recommended land disposal due to the broader political considerations mentioned above (Lintner pers. comm., 1989).

The Government of Egypt issued Law 48 in 1982. This law and subsequent modifying decrees set better-than-primary standards for effluent quality discharged into rivers, lakes, canals, and drains. These standards have not yet been met by any major urban center.

1.1.2 Phase II Project Design

When the Canal Cities Phase II Project Identification Document (PID) was prepared (USAID 1985), USAID intended that two primary wastewater treatment plants would be built at Suez: one in the north near the Suez Sweetwater Canal whose effluent would be used for irrigation, and one in the south with discharge to Suez Bay. This new approach was based on the 1979 Master Plan and further investigations by the Canal Cities Project Phase I consultant, Canal Cities Consultants. Their 1982 studies included an infiltration pilot trial at Ismailia and a feasibility study of land application at Suez, which did not include infiltration trials.

The Phase II Project Paper (PP) reverted to one treatment plant at Suez and land disposal by rapid infiltration. Rapid infiltration beds, a proven wastewater treatment process in the United States, avoided the need for a marine discharge. The facility was intended to be north of the city and would employ screening and deep anaerobic lagoons. The PP referred to the system as "primary," even though the level of treatment would have been greater than simple screening and settling. The design team evidently saw no problem with acquisition of suitable sites for land disposal, stating that some 33,000 feddans were available to choose from (USAID 1987).

The PP design team based its elimination of effluent discharge into Suez Bay on the 1979 Master Plan's water quality modeling findings, stating that the Bay can assimilate safely only 185,000 m^3/day of secondary-treated effluent. Since USAID at that time would not fund secondary treatment, and population projections showed that a 200,000 m^3/day plant would be needed to meet year-2000 flows, the team deemed discharge to the bay unacceptable. They found "primary" treatment and land disposal more cost effective and environmentally sound than secondary treatment and discharge to Suez Bay or putting primary-treated effluent into the Gulf.

1.1.3 Current Phase II

Phase II preliminary design and construction-related activities are being managed for NOPWASD and USAID by Construction Management Consultants (CMC), a team supplied through a joint venture of Black & Veatch International and James M. Montgomery of the United States, in association with Sabbour Associates of Egypt.

Phase II began in late 1988 intending to implement the PP's wastewater treatment and disposal schemes for the three cities. Questions quickly arose over the feasibility of rapid infiltration at Suez because of the lack of sufficient suitable land area within an affordable distance of the city and because of high groundwater levels. The amount of land required at Suez was 4,200 feddans, and the most attractive site, about 15 km to the north, was already committed to private companies for land reclamation. Smaller parcels of land suitable for a conventional wastewater treatment facility were available within the city boundaries.

Furthermore, population growth in the city did not occur as rapidly as expected during preparation of the Facilities Master Plan. Finally, reconstruction of the city and its petroleum industry facilities, deepening and widening of the Suez Canal, and potential increases in shipping traffic may have modified pollutant loadings or circulation patterns in the bay. Given these factors and the realization that the proposed land application site to the north of Suez was no longer available for this use,

CMC was authorized by USAID/Cairo to conduct studies of alternate wastewater treatment facilities for Suez (Task Order No. 9).

The CMC's Alternative Treatment Study (1989) recommended a treatment system based on aerated lagoons and a marine discharge either to Suez Bay or the Gulf of Suez. Discharge to the bay reemerged as a strong candidate partly because actual Suez population growth was slower than had been forecast. Thus, a year-2005 treatment plant capacity of about 130,000 m^3/day could be built rather than the year-2000 capacity of 200,000 m^3/day. This is well under the 185,000 m^3/day flow of secondary-treated effluent that the 1979 Master Plan found the Bay could absorb. Furthermore, the aerated lagoon system can provide a better-than-primary level of treatment.

1.2 Proposed Action

NOPWASD and USAID have agreed that an aerated lagoon treatment method should be used by the proposed Suez wastewater treatment plant, basing their decision on considerations of cost, simplicity of operation, land requirements, and effluent quality. The treatment plant will be located on the west shore of the Suez Bay in the industrial zone about 4 km southwest of the existing facility, and it will discharge treated effluent to Suez Bay. The proposed action will vastly improve the quality of wastewater now flowing into Suez Bay from Suez.

Nevertheless, proposed construction of the new facilities has raised several environmental concerns that require further analysis. The CMC's proposed wastewater treatment facilities would produce an effluent with a maximum of 60 mg/l 5-day biochemical oxygen demand (BOD_5) and 50 mg/l total suspended solids (TSS). These levels meet the respective criteria for a Law 48 effluent and are, therefore, superior to primary treatment. It would not meet the requirements recommended in the Master Plan (Pirnie-Harris International 1979).

NOPWASD, in association with USAID, is conducting this Environmental Assessment (EA) of the proposed new sewage treatment plant for Suez City. This document intends to inform NOPWASD and USAID decision-makers, as well as other concerned parties, about existing environmental conditions, potential environmental impacts of the proposed project's construction and operation, possible mitigating measures and monitoring programs, and opportunities for environmental enhancement The findings support the ongoing design of the facility and its future management. Final USAID authorization of construction funding depends on approval of the EA.

The EA is just one element of a multifaceted project appraisal process. Other equally important elements include: technical soundness analysis, economic and finan-

cial benefit-cost analysis, and social soundness analysis. USAID policy requires preparation of an EA on all projects it funds that have or potentially have significant environmental impacts. Egypt's own laws require that certain environmental conditions be met by new wastewater treatment facilities, most notably, the effluent standards established by Law 48 of 1982 and Ministerial Order No. 8/1983.

As part of preparation of the EA, scoping meetings were held in Cairo on 8 February 1990 and in Suez on 11 February 1990. The purpose of the scoping meetings was to bring together parties with an interest in the proposed new wastewater treatment plant to assist NOPWASD in identifying environmental issues that should be addressed by the EA. The scoping meeting in Cairo was held in reference to the proposed construction of wastewater treatment plants in Ismailia and Port Said, as well as the proposed plant in Suez. Participants were invited to voice their concerns, questions, and comments regarding technical and environmental aspects of the planned wastewater treatment plant. Participants were further invited to submit comments in writing to the CMC by 1 March 1990. The scoping report and a list of attendees at the scoping meetings in Cairo and Suez are attached as Appendix A.

1.3 USAID Environmental Procedures

USAID's environmental procedures are found in 22 CFR Part 216, and are further explained in the Agency's Handbook 3, Appendix 2D. These guidelines, which were adopted in 1976 and revised in 1980, formalize the agency's commitment to environmental considerations during the decision-making process leading to implementation or rejection of a project. Within the process, reasonably foreseeable environmental impacts are identified, and alternatives or mitigating measures are recommended.

For projects falling in various classes of actions (Sect. 216.2.d), including potable water and sewerage projects other than those that are small scale, either an Environmental Assessment (EA) or Environmental Impact Statement (EIS) will be required (Sect. 216.2.d.1.xi). Thus, an EA or EIS is required for the proposed Suez wastewater treatment plant.

An EA is defined as "a detailed study of the reasonably foreseeable significant effects, both beneficial and adverse, of a proposed action on the environment of a foreign country or countries" (Sect. 216.1.c.4). It must be prepared when an EIS is deemed unnecessary according to the criteria in Sect. 216.7.

An EIS is defined as "a detailed study of the reasonably foreseeable environmental impacts, both positive and negative, of a proposed AID action and its reasonable alternatives on the United States, the global environment or areas outside

the jurisdiction of any nation as described in Sect. 216.7 of the procedures" (Sect. 216.1.c.5). It must be prepared when "agency actions significantly affect... (1) the global environment or areas outside the jurisdiction of any nation (e.g., the oceans); (2) the environment of the United States; or (3) other aspects of the environment at the discretion of the Administrator" (Sect. 216.7.a). In the case of (1) and (3) above, an EIS, "will generally follow the CEQ Regulations, but will take into account the special considerations and concerns of AID."

Executive Order 12114 (Environmental Effects Abroad of Major Federal Actions), with which Regulation 16 is "consistent" (Sect. 216.1.a), states that an EIS must be prepared "with respect to actions... significantly affecting the environment of the global commons outside the jurisdiction of any nation (e.g., the oceans or Antarctica)."

USAID has determined (State Cable 077708, 11 Mar 1990) that an EIS will not be necessary for the proposed Suez wastewater treatment plant (WWTP). It states that the project will not have a significant effect on the "global environment or areas outside the jurisdiction of any nation (e.g., the oceans)" (Sect. 216.7.a.1), because Suez Bay, according to "reasonably accepted legal definitions," extends only 3 miles within the 12 mile limits of Egypt's territorial waters. "While there will be some net transport of nutrients out of Suez Bay into the Gulf of Suez, the impact to the Gulf water quality will be minor due to dilution and dispersion... There will be no impacts beyond the Gulf of Suez in international waters... Therefore, preparation of an EA for the Suez City WWTP is appropriate fulfillment of agency environmental procedural requirements."

1.4 Egyptian Environmental Legislation

The two major environmental laws affecting wastewater discharges and water quality considerations in Egypt are Law 48/1982 and Law 93/1962. Law 48, entitled "Protection of the River Nile and Waterways from Pollution" was promulgated in 1982 and is focused on protecting freshwater resources that are required for both potable and non-potable/agricultural use. Law 48 particularly applies to the River Nile and its distributed waters that are used for irrigation purposes. For these waters, Law 48 supersedes the older Law 93, promulgated in 1962, entitled "Quality Standards for Wastewater Disposal." After its passage in 1982, a five-year moratorium on enforcement of the new water pollution law (Law 48) was enacted (Baldwin et al. 1988).

The applicable standards set under Law 48 for discharges of treated wastewater effluent ("Sanitary Drainage Water") are summarized in Table 1-1. There are no clear or unequivocal regulations for Law 48 indicating how the sanitary wastewater

specifications shown in Table 1-1 are to be measured and at what distance from the point of discharge.

A careful reading of Law 48 suggests that the law was principally enacted to protect Egypt's irrigation water from possible sources of contamination. In this regard the law applies unambiguously to the Nile River, irrigation canals, freshwater lakes, and underground aquifers. Its definition of "waterways" as stated in Article 1 of both Law 48 and the accompanying Decree No. 8 promulgating regulations for its enforcement do not explicitly refer to marine water bodies or discharges to such bodies.

This point is significant since the proposed outfall discharge being considered by the CMC involves the marine environment. Nevertheless, a recent report prepared for USAID/Cairo suggests that NOPWASD has responsibility for establishing and enforcing environmental standards in addition to its primary responsibilities for developing potable water supply and wastewater treatment projects (Baldwin et al. 1988). Therefore, compliance of USAID's project with Law 48 seems indicated as a matter of policy.

Law 93/1962 concerning the discharge of liquid wastes was amended in 1989 by Ministerial Decree Number 9, and sets standards and specifications required for liquid wastes to be discharged into public sewerage networks, surface drainage systems, and to irrigate cultivated lands. Public wastewater is named as First Category liquid wastewater by Law 93, and related standards are summarized in Table 1-2. Other conditions include:

- In the case of wastewater treatment plants, a permit shall be obtained from the Ministry of Health for the chosen site for effluent discharge before building the plants.

- Treatment of liquid wastes... shall not be less than primary treatment.

- Water shall be discharged with a velocity that shall not permit water accumulation.

Thus, a permit is required from the Ministry of Health prior to construction of the proposed Suez WWTP outfall.

The Egyptian Environmental Affairs Agency was created in 1983 by Prime Ministerial Decree (No. 631/1982) and is administered by the Minister of Cabinet Affairs. Its purpose is to prepare a national plan for environmental studies, analyze proposals on environmental affairs, follow up on implementation of environmental laws, and advise the Cabinet with respect to environmental matters. It is an advisory and coordinating entity with no regulatory authority except to manage newly established

Table 1-1. Law 48 Wastewater Effluent Specifications[a].

Description	Sanitary Drainage Water
Temperature	35°C
Hydrogen Exponent (pH)	6-9 pH units
Absorbent activated oxygen (BOD_5)	60
Consumed chemical oxygen (Dichromate)	80
Consumed chemical oxygen (Permanganate)	40
Dissolved oxygen	Not less than 4
Oils and greases	10
Dissolved substances	2000
Suspended substances (TSS)	50
Colored substances	Free of colored substance
Sulphides	1
Nitrate	50
Total of heavy metals	1
Different kinds of insecticides	Nonexistent
Probable counting in colon group in 100 cm^3	5000 MPN

a: Maximum limit for the standard measures and specifications (milligram/liter, unless mentioned otherwise).

Source: Law 48/1982 and Ministerial Order No. 8/1983 for Protection of River Nile and Water Bodies against Pollution (English translation from Arabic original).

Table 1-2. Decree 9 (Law 93/1962) Standards for Liquid Wastes.

Description	Liquid Wastes Discharged From Public Areas[a]
Temperature	40°C
pH	6 - 10 units
Soluble material	2000 mg/l
Suspended material[b]	500 mg/l
Biochemical oxygen demand	400 ppm
COD (Dichromate)	700 ppm
COD (Permanganate)	350 ppm
Sulphates	10 ppm
Cyanides	0.1 ppm
Phosphates	5 ppm
Nitrates	30 ppm
Fluorides	1 ppm
Phenol	0.005 ppm
Ammonia	100 ppm
Free chloride	10 ppm
SO_4	1 ppm
Formaldehyde	10 ppm
Grease, oil, resins	100 ppm
Silver, Mercury, Copper, Nickel, Zinc, Chromium, Cadmium	single or combined 10 ppm[c]
Silver and Mercury	1 ppm
Ether petrol, calcium carbide, organic solvents	0 ppm

a: Maximum limit for discharge to public sewerage systems and surface drainage systems.

b: Residual should < 5 $cm^3/l/10$ minutes and < 10 $cm^3/l/30$ minutes.

c: If the discharges are less than 50 m^3/day; 5 ppm if discharges exceed 50 m^3/day.

Natural Protectorates. Although representatives of the Agency participated in the scoping meetings for this EA, current law does not provide for formal environmental impact assessment procedures or certification of environmental impact assessment documents.

1.5 International Conventions on Environmental Protection

Egypt claims a 12-mile territorial limit and a 200-mile Exclusive Economic Zone (EEZ). If one assumes that the potential receiving water bodies at Suez fall either within Egypt's territory or its territorial waters, then one could make the case that only USAID and Egyptian environmental regulations would apply. However. Egypt is also a signatory to several international agreements which create a more ambiguous situation. Egypt is a signatory to the Red Sea and Gulf of Aden Action Plan administered by the U.N. Environmental Programme's (UNEP) Regional Seas Programme.

The UNEP Red Sea Action Plan clearly defines the area to be included in the protocols on conservation of the marine environment and coastal areas as: the Red Sea, the Gulf of Aqaba, the Gulf of Suez, and the Suez Canal to its connection with the Mediterranean (UNEP, 1986). This program is designed to prevent discharges of oil, toxic wastes and other forms of ocean dumping, rather than controlled discharges of treated wastewater. It does not appear that additional protocols related to controlling pollution from land-based sources have been developed since 1986 as originally planned, although guidelines for submarine outfalls in the Mediterranean have been issued jointly be the World Health Organization and UNEP, (WHO/UNEP, 1989) under a similar protocol for the Mediterranean. This latter protocol and its guidelines are not applicable to the Suez project. Thus, discharge of effluent to Suez Bay appears to be in compliance with international conventions regarding pollution of the Red Sea.

CHAPTER 2

2.0 PROPOSED FACILITIES AND ALTERNATIVES CONSIDERED

2.1 Introduction

This chapter describes the proposed facilities and wastewater treatment alternatives considered for the City of Suez, Arab Republic of Egypt. Facilities and alternatives were developed in a report prepared by CMC entitled "Final Report on Alternative Treatment Study for the City of Suez, Arab Republic of Egypt" dated 22 October 1989.

Population estimates used in the Alternative Treatment Study report have been subsequently revised to reflect current conditions of employment and housing. In this revised report, entitled "Canal Cities - Phase II Project Population and Flow Study," two projections of growth have been made by CMC (1989). A low growth projection anticipates a population of about 480,000 in the year 2000 and 654,000 in the year 2010. The high growth projection anticipates a population of 510,000 in the year 2000 and 781,000 in 2010. Both projections are lower than a population of 678,294 that was projected for the year 2005 in the Alternative Treatment Study report.

2.2 Wastewater Flow Projection and Plant Capacity

Wastewater flow projections included in the Alternative Treatment Study report have been revised by CMC (1989). A program of flow measurements established current pump station flows and per capita flows. Based on these data, the total of all measured flows tributary to the existing treatment plant is 67,300 m^3/day. This plant serves an estimated population of 273,100 persons, although a large percentage of the flow bypasses the treatment plant and combines with the treated flow downstream of the plant. The per capita flows are approximately 246 l/day.

Future flow projections have been made (CMC 1989) assuming a base flow of 67,000 m^3/day and low population growth projections. Future increases are based on a per capita sewage flow of 215 l/day for residential/commercial and 75 l/day for industrial, institutional, and infiltration flow components. Projected populations and wastewater flows are as follows:

	Year					
	1990	1995	2000	2005	2010	2015
Total Population	333,000	409,400	480,600	561,800	653,800	737,700
Sewered	273,100	349,000	408,500	483,100	575,300	681,900
1990 Base Flow (m^3/day)	67,200	67,200	67,200	67,200	67,200	67,200
Future Flow Increase (m^3/day)	0	20,530	39,271	60,900	87,643	118,500
Projected Avg. Flow (m^3/day)	67,200	87,700	106,500	128,100	156,800	185,800

Based on these projections, a treatment capacity of 130,000 m^3/day is required in the year 2005. This new information on population and flows allows the project to extend the planning horizon from the year 2000, as originally intended in project design, to the year 2005.

2.3 Influent Characteristics

Wastewater sampling was performed to provide key wastewater data for estimating wastewater characteristics. The sampling data in the Alternatives Treatment Study report have also been updated by data collected by CMC in January 1990. The results of the updated sampling are in Table 2-1. Key characteristics are estimated as follows:

- Total Suspended Solids (TSS) at 400 mg/l;
- 5-day biochemical oxygen demand (BOD_5) at 280 mg/l; and
- Total nitrogen at 40 mg/l.

2.4 Effluent Requirements

Wastewater effluent must meet the requirements of Egyptian Law 48 for TSS and BOD_5. These requirements are as follows:

- TSS - 50 mg/l; and
- BOD_5 - 60 mg/l.

2.5 Plant Siting

Suez currently is served by an existing facility located 3 km northwest from the urban area. This plant has anaerobic and facultative sewage ponds. This site has a treatment capacity after plant upgrade of 60,000 m^3/day. The proposed site for the wastewater treatment plant (WWTP) is 8 km southwest of Suez. This site is approximately 875 meters by 600 meters. The locations of the existing and proposed treatment plant sites are shown on Figure 2-1.

Table 2-1. Canal Cities Wastewater Composition (mg/liter).

	Suez	Ismailia	Port Said	Average values in U.S.[a]
Total Dissolved Solids (TDS)	5,300	910	1,400	500
Total Suspended Solids (TSS)	400	240	330	220
Volatile Suspended Solids	140	200	230	165
BOD_5	280	270	300	220
COD	510	450	520	500
Nitrogen (total N)	40	40	50	40
Phosphorus (total P)	9	9	9	8
Alkalinity ($CaCO_3$)	330	300	310	100
Hardness	1,060	400	370	
Oil/Grease	60	70	70	
Dissolved Inorganic Solids				
Calcium	200	60	60	
Magnesium	120	50	50	
Sodium	410	130	210	
Potassium	60	20	40	
Chloride	1,210	380	720	
Sulfate	540	170	180	
Sulfide	6	2	5	
SiO_2	3	3	2	
Heavy Metals				
Cadmium	0.05	0.04	0.06	
Copper	0.5	0.5	0.6	
Iron	0.3	0.3	0.4	
Lead	0.2	0.5	0.3	
Manganese	ND	--	ND	
Mercury	0.03	0.02	0.03	
Nickel	0.09	0.10	0.09	
Selenium	--	ND	ND	
Zinc	0.4	0.4	0.4	

ND = Not Detected

a: Average U.S. water comsumption rate per capita is about 4 times rate in Canal Cities.

Source: NOPWASD Canal Cities Water and Wastewater Phase II Project, Final Report on Alternative Treatment Study: Suez City, Ismailia, and Port Said (Cairo: October 22, 1989), and subsequent testing by CMC, December 1989-January 1990.

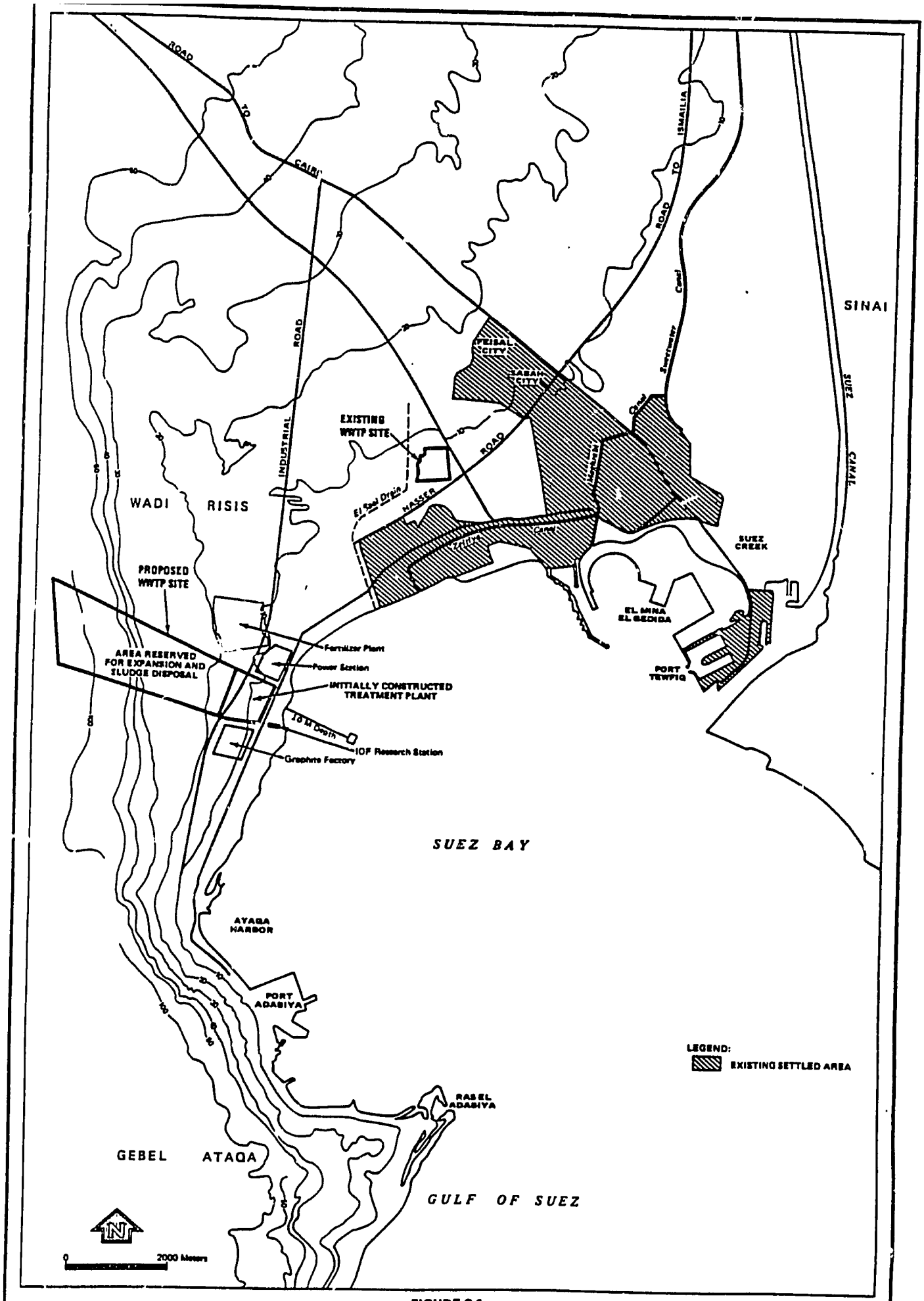


FIGURE 2-1
SUEZ AREA

Dames & Moore

2.6 Wastewater Collection Facilities

Wastewater collection facilities consist of gravity sewers, pump stations, and force mains. Existing facilities include three pump stations that pump to the existing site via separate force mains. A schematic of the existing system is shown on Figure 2-2.

New facilities have been identified to feed the new sites. These facilities (Figure 2-3) consist of Pump Station No. 11 (Ataqa Pump Station) with a capacity of 3,600 l/sec, a 1.4 km 1,200-mm diameter force main connecting the new pump station to the proposed WWTP, and a 4.1 km 1,800-mm diameter SW Main Trunk Sewer connecting the existing collection system to the new pump station. The estimated cost for these facilities is $6,703,000.

2.7 Wastewater Treatment Alternatives

Five alternative wastewater treatment process trains were considered in the Alternative Treatment Study report for Suez. These alternatives do not reflect the revised wastewater characteristics and flows and are based on a treatment plant capacity of 140,000 m^3/day (annual average flow). Rapid infiltration land treatment was analyzed at two sites. Conventional treatment processes were analyzed at a third site. A description of each treatment process follows:

2.7.1 Rapid Infiltration Land Treatment

Rapid infiltration land treatment consists of using the soil for treatment and removal of BOD, TSS, nitrogen, and phosphorus. The wastewater would be given primary treatment prior to land application. Particulate BOD and suspended solids would be removed by filtering through the soil. Soluble BOD would be absorbed by the soil or oxidized by soil bacteria. Nitrogen would be removed by nitrification-denitrification bacteria in the soil. Phosphorus would be removed by absorption and precipitation. The wastewater effluent either flows into nearby waterways or is collected in underdrains and disposed of at another location.

Rapid infiltration was analyzed at two sites. One site (Site A) was located on the north side of Suez 8 km from the existing plant. The site has an area of about 7,000 feddans (1 feddan = 4,200 m^2, or 1.04 acres) and is considered generally favorable for rapid infiltration. However, the Governorate recently determined that the site was not available due to future use for agricultural development. The second site (Site B) was located approximately 45 km south of the existing plant. The site has an area of over 10,000 feddans and appears suitable for rapid infiltration.

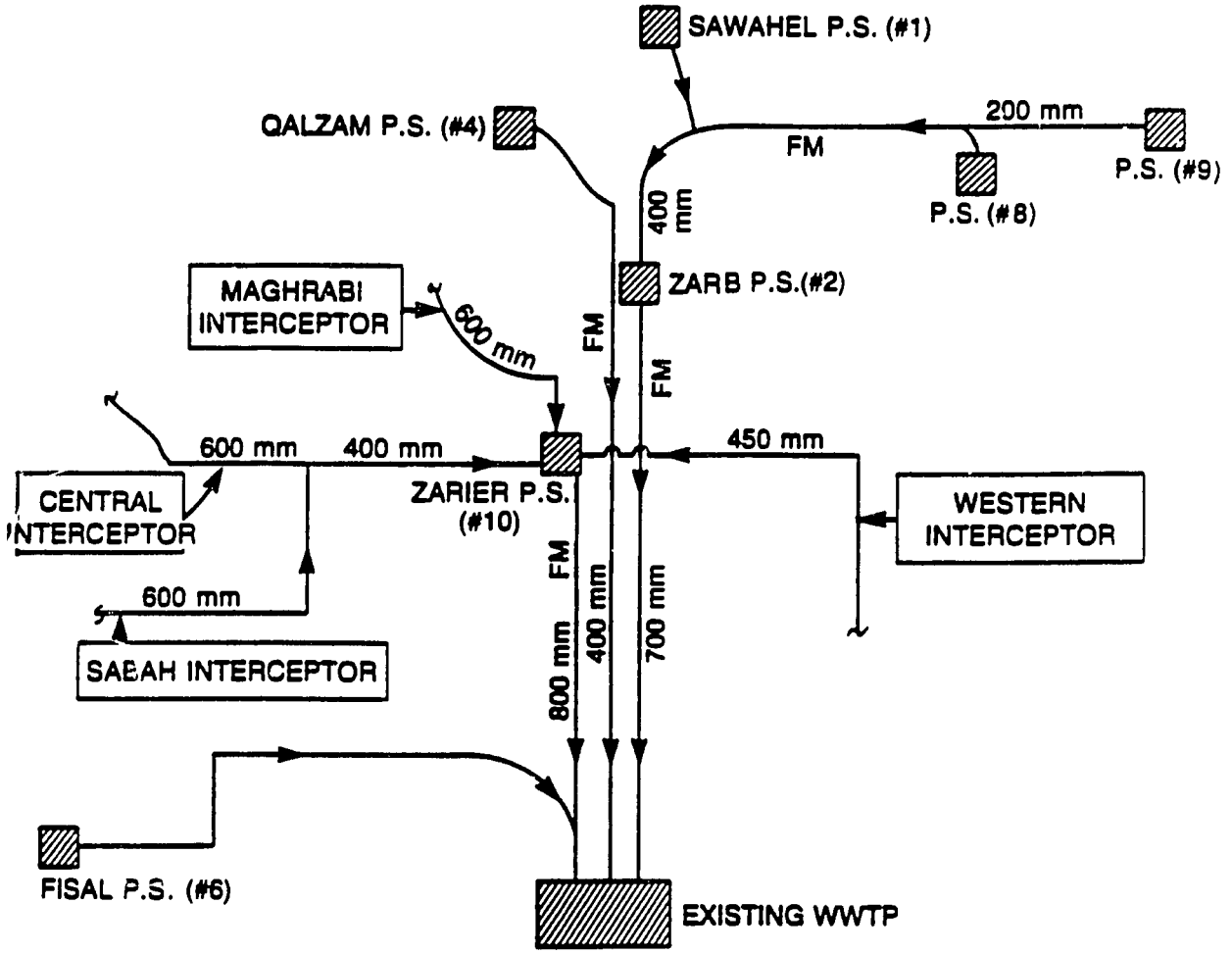


FIGURE 2-2
SUEZ
SCHEMATIC – EXISTING PUMP STATIONS
AND FORCE MAINS

Dames & Moore

A comparison of present worth costs between the rapid infiltration process at Site B (45 km south) and a conventional secondary treatment plant at the site now being considered (8 km southwest of Suez) indicates that the present worth cost of the latter plant is 20 percent lower than the rapid infiltration alternative. The major cost difference was due to the costs of the force main required to transport the sewage to Site B. The capital cost for rapid infiltration at Site B would be about 90 percent more than the budgeted amount. Therefore, rapid infiltration is not considered to be cost effective when compared to a conventional treatment plant located at the proposed site shown in Figure 2-3, and is not considered further.

2.7.2 Conventional Treatment Processes

The conventional treatment process alternatives that were analyzed provide secondary treatment capable of meeting and probably exceeding the requirements of Egyptian Law 48 for BOD_5 and TSS. The alternatives consist of: the deep shaft process with or without primary tanks; activated sludge with or without primary tanks; aerated lagoons; and trickling filters. All alternatives analyzed in the Alternative Treatment Study include preliminary treatment consisting of bar screens and grit removal, and effluent treatment consisting of disinfection and post-aeration. Primary treatment consists of circular primary clarifiers.

2.7.2.1 Common Facilities

A description of the common facilities for each alternative as it was analyzed in the Alternative Treatment Study is as follows:

- Bar Screens. Four mechanically cleaned bar screens, each with rated hydraulic capacity of 93,000 m^3/d will be provided. One unit can be taken out of service at peak flow conditions (280,000 m^3/d).

- Grit Removal. Grit removal is provided by four aerated grit tanks. Each unit has a volume of 160 m^3 and air supply of 5.2 sm^3/min to keep organic matter in suspension. Related equipment for grit washing and disposal of screenings and grit will be provided.

In addition to the bar screens and grit removal facilities, the Alternative Treatment Study report also analyzed disinfection, post-aeration, and primary clarifiers as common facilities for all conventional treatment alternatives. Descriptions of these follow. Since the preparation of the Alternative Treatment Study report, additional work on preliminary design suggests that these facilities may not be needed. The analysis in the remainder of this chapter, however, assumes that these facilities will be

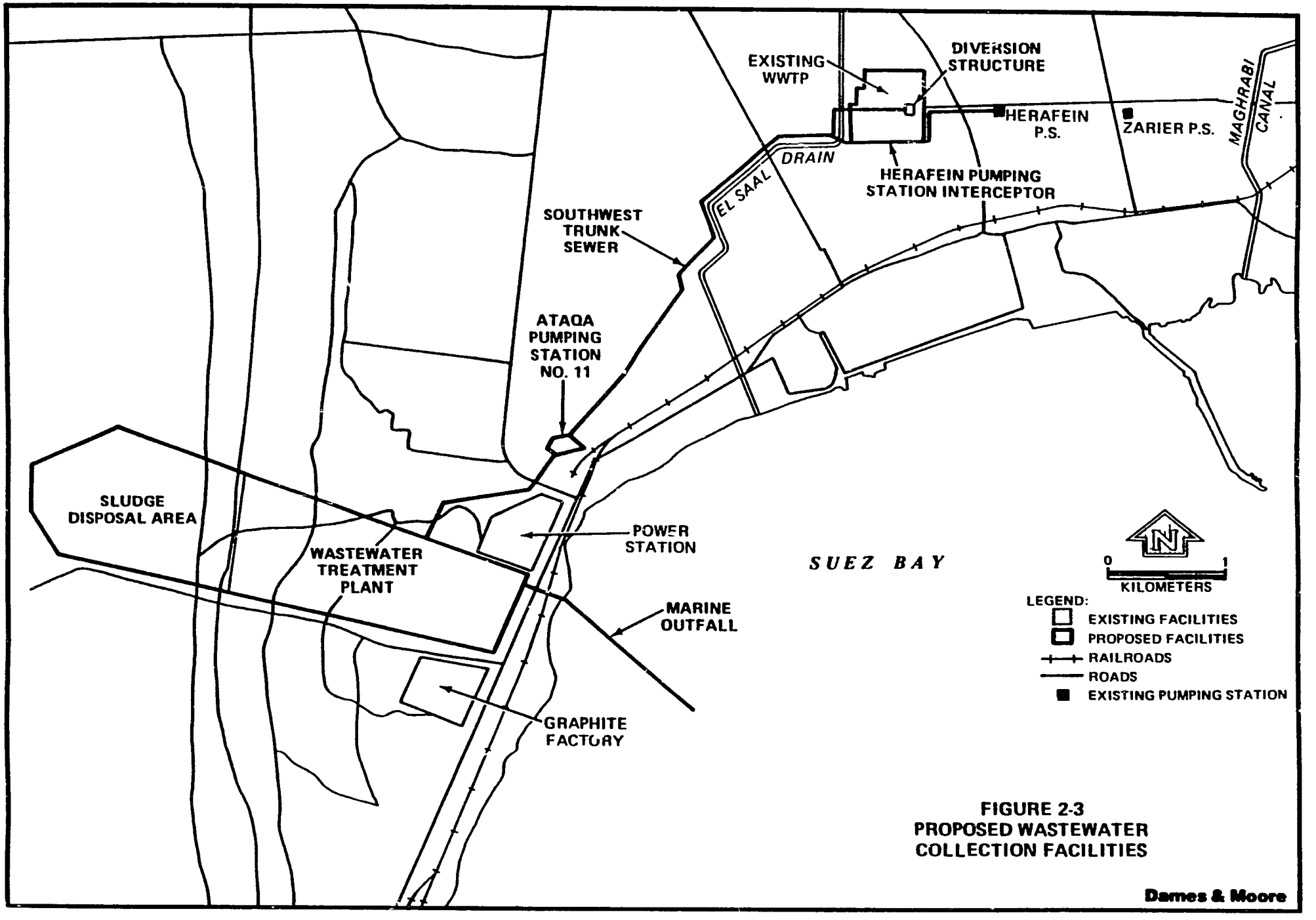


FIGURE 2-3
PROPOSED WASTEWATER
COLLECTION FACILITIES

required. No new calculations of present worth, operation and maintenance (O&M), or capital costs have been made without these components.

- o Disinfection. Disinfection is accomplished by chlorination. Two chlorine contact basins, each 33 m long and 16.5 m wide with 1,633 m^3 volume will be provided. Two rapid mix units with 27 m^3 volume and 9.2 horsepower each will be installed. Estimated chlorine quantities required are 700 kg at average daily flow and 2,800 kg at peak flow. Related equipment for chlorine storage and injection will be included in the facilities. The CMC is currently re-evaluating the requirements for disinfection at Suez. The requirement for disinfection would be the same for all alternatives and should not affect process selection.

- o Post-aeration. Post-aeration facilities consist of two diffused aeration basins. Each unit will have a length of 7.5 m and width of 7.5 m and a depth of 5.5 m.

- o Primary Clarifiers. Primary clarifiers are used with Deep Shaft Process, Activated Sludge, and Trickling Filters. Deep shaft and activated sludge processes are also evaluated without the primary clarifiers.

The following design criteria were used in sizing the primary clarifier units:

Surface overflow rate, $m^3/day/m^2$	
at avg. flow	32.6
at peak flow	65.2
Side water depth, m	4
SS removal, %	50
BOD removal, %	20[a]
Solids concentration, %	4

(a) Low BOD removal is anticipated due to septic conditions and high soluble BOD.

A summary of the bar screen and grit removal facilities is shown in Table 2-2, along with the primary clarifier facilities.

2.7.2.2 Deep Shaft Process

The deep shaft process is a proprietary process by Deep Shaft, Inc. The deep shaft process is a high rate activated sludge process. A vertical shaft 90 to 250 m deep with a 1-hr detention time is divided into two sections, a downcomer and a riser. Wastewater and return sludge enter the downcomer, and mixed liquor is withdrawn at

Table 2-2. Required primary and common facilities.

Process Unit	Parameters
Common Facilities	
o Bar Screens	
No. of units	4
Capacity, m^3/day, ea.	93,000
Bar width, mm	15
Bar spacing, mm	19
o Grit Removal	
Aerated grit tanks	
No. of units	4
Length, m	8
Width, m	5
Depth, m	4
Volume, m^3, ea.	160
Air supply, sm^3/min., ea.	5.2
Primary Clarifier	
No. of units	4
Diameter, m	37
Side water depth, m	4

the riser. Oxygen is provided by compressed air introduced into the downcomer and riser. Mixed liquor is settled in secondary clarifiers prior to discharge. Sludge settles in the clarifier and is either returned to the shaft or is removed from the system and treated for disposal (Sect 2.7.3).

The design criteria used to develop this process are as follows:

Organic Loading Rate	3 kg BOD/m^3/day
F/M Ratio	1 day
MLSS	4,000 mg/l
Solids Retention Time	1.2 days
Oxygen Requirements	1 kg O_2/kg BOD Removed
Sludge Production	1.4 kg sludge/kg BOD Removed

2.7.2.3 Conventional Activated Sludge (CAS)

The conventional activated sludge method consists of a completely mixed tank of activated sludge aerobic micro-organisms. Mixing and oxygen are provided by compressed air. Wastewater and return sludge are introduced into the front of the tank. Mixed liquor is discharged to secondary clarifiers. Sludge settles in the clarifiers and is either returned to the aeration tank or removed from the system and treated for disposal. This process has been analyzed with and without primary treatment.

The design criteria used to develop this process are as follows:

BOD Load	
Avg.	0.5 - 0.6 kg/m^3
Max.	0.7 - 0.8 kg/m^3
F/M Ratio	0.34 - 0.57/day
MLSS	1,500 - 3,000 mg/l
SRT	3 - 4 days
Oxygen Required	1.2 - 1.4 kgO_2/kg BOD
Minimum DO	2 mg/l

2.7.2.4 Aerated Lagoons

Aerated lagoons consist of three ponds in series: a complete mix lagoon, a partial mix lagoon, and a polishing pond. The wastewater receives preliminary treatment with bar screens and grit removal prior to the aerated lagoons. The complete mix lagoon keeps solids in suspension with mechanical mixers or diffused aeration systems. These systems provide the oxygen for aerobic oxidation of the wastewater. The partial mix lagoon provides oxygen for BOD removal but not enough mixing to keep solids in suspension. Settled solids are degraded by anaerobic bacteria.

The polishing ponds provide final treatment and sludge settling. Preliminary facility layout at the Suez site is shown on Figure 2-4. It is anticipated that two complete treatment lagoon trains will be provided.

The design criteria used to develop this process are summarized as follows:

Complete Mix Lagoon

Retention Time	1 day
Depth	5 m
Oxygen Requirements	1.6 kg O_2/kg BOD
Mixing	15 m^3/1,000 m^3

Partial Mix Lagoons

Retention Time	5 days
Depth	5 m
Oxygen Requirements	1.0 kg O_2/kg BOD

Polishing Pond

Retention Time	5 days
Depth	3 m

The required facilities for the aerated lagoon process are shown in Table 2-3.

2.7.2.5 Trickling Filters

Trickling filters consist of a circular bed of rock or permeable plastic media. Aerobic organisms attach and grow on the media. The wastewater is applied to the media, and BOD is oxidized by the organisms attached to the media as it passes through the filter. Excess organisms slough off the media and are settled in secondary clarifiers. Settled sludge material is removed from the system and treated for disposal. Clarified effluent may be recycled to the trickling filter. Wastewater receives preliminary and primary treatment prior to the trickling filter.

The design criteria used to develop this process are summarized as follows:

Organic Loading	
avg.	0.9 kg BOD/d/m^3
max.	1.3 kg BOD/d/m^3
Hydraulic Loading	60 m^3/d/m^2
Depth	6 m
Diameter	38 m

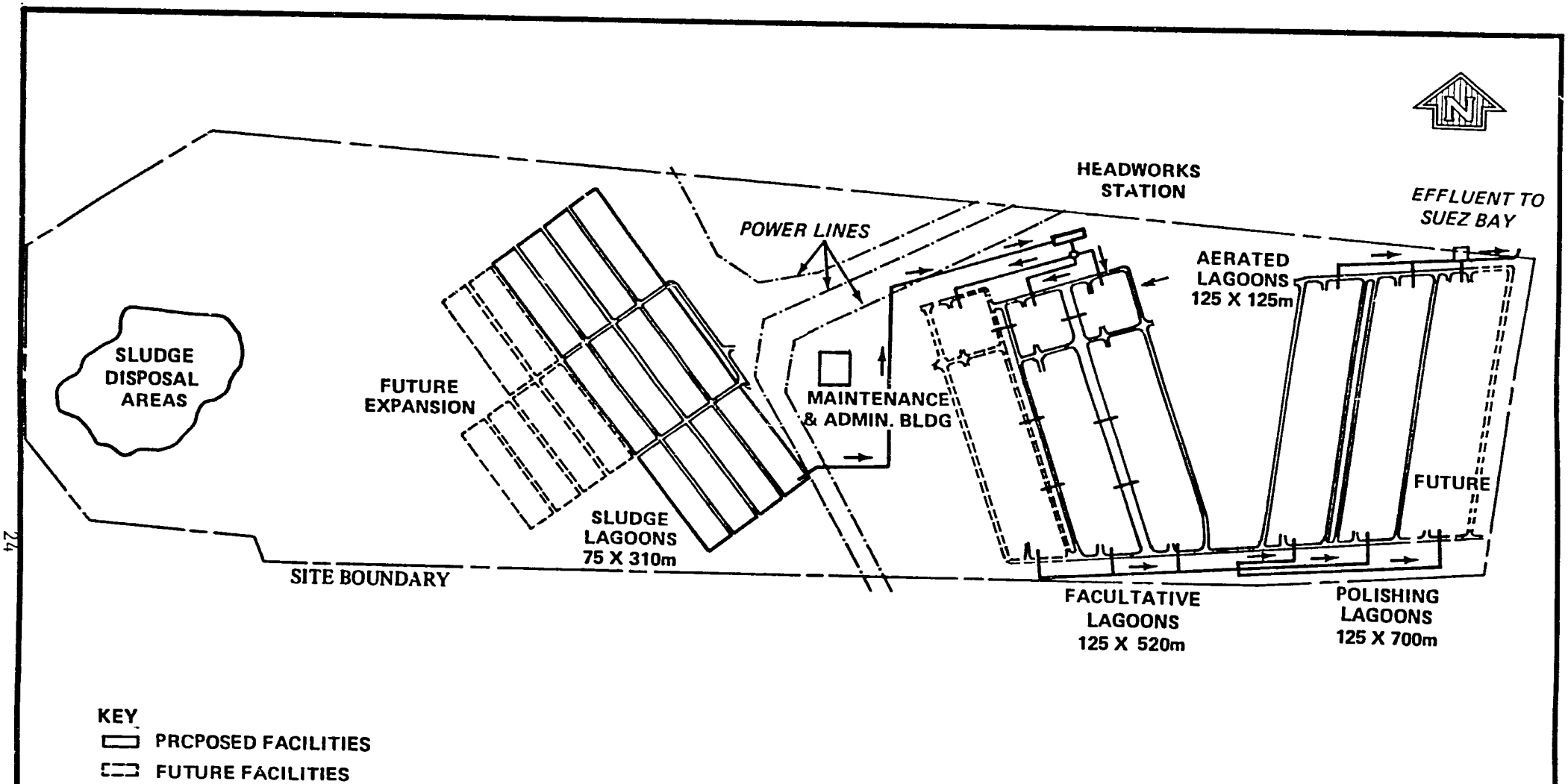


FIGURE 2-4
AERATED LAGOON TREATMENT PLANT LAYOUT

Dames & Moore

Table 2-3. Required facilities for aerated lagoons.

Process Unit	Parameter
Complete Mix Lagoons	
No. of units	1
Length, m @ bottom, ea.	149
Width, m @ bottom, ea.	149
Depth, m	5.2
Freeboard, m	1
Sideslope	3:1
Hydraulic retention, days	1.0
Total volume, m^3	141,300
Diffuser type [a]	Static Aerator
No. of diffusers	3,330
Air supply, sm^3/min	2,115
Partial Mix Lagoon	
No. of units	1
Length, m @ bottom, ea.	556
Width, m @ bottom, ea.	220
Depth, m	5.2
Freeboard, m	1
Sideslope	3:1
Hydraulic retention, days	5.0
Total volume, m^3	700,310
Diffuser type [a]	Static Aerator
No. of diffuser	2,300
Air supply, sm^3/min, avg.	1,490
peak	1,940
Blowers	
Total, whp, avg	5,149
peak	6,146
Polishing Pond	
No. of units	1
Length, m @ bottom, ea.	642
Width, m @ bottom, ea.	350
Depth, m	3.0
Freeboard, m	1
Sideslope	3:1
Hydraulic retention, days	5.0
Total volume, m^3	700,800

a: Decision between surface aeration and submerged diffusers will be made during detailed design.

2.7.3 Sludge Handling

Sludge treatment consists of thickening, stabilization, dewatering, storage, and disposal. Various unit processes for each sludge treatment step were considered as shown on Table 2-4. Alternative process trains for each wastewater treatment train were developed and analyzed. Costs for each alternative sludge processes for each treatment alternative are described in the Alternative Treatment Study prepared by CMC. Recommended sludge treatment trains for each wastewater treatment alternative are shown on Figure 2-5.

Wastewater Treatment Process	Sludge Handling Process			
	Thickening	Stabilization	Dewatering	Disposal
Deep shaft with or without primary tanks	Gravity thickener	Facultative lagoon	Sludge drying lagoon	Dedicated land application
Activated sludge with or without primary tanks	Gravity thickener	Facultative lagoon	Sludge drying lagoon	Dedicated land application
Aerated lagoons	---	---	Sludge drying lagoon	Dedicated land application
Trickling filters	---	Facultative lagoon	Sludge drying lagoon	Dedicated land application

Thickening and stabilization are not required for the aerated lagoon process. The aerated lagoon sludge has a high solids content and is stabilized as part of the wastewater treatment process. Sludge concentrations from the trickling filter clarifiers are high enough so that additional thickening is not required, but stabilization is still required.

In all cases the processes selected have the lowest capital cost and O&M costs, are very reliable, and are easy to operate.

2.7.3.1 Gravity Thickener

A gravity thickener consists of a circular concrete tank in which solids are allowed to settle and thicken. Solids are collected by a mechanism in the center of the tank. The design criteria for this process are as follows:

Table 2-4. Preliminary evaluation of sludge treatment alternatives.

Function	Unit Process	Comments
Thickening	Dissolved Air Flotation	High cost, mechanical/energy intensive
	Gravity Belt Filter	Low cost, reliable, easy to operate
	Gravity Thickener	Low cost, reliable, easy to operate
	Centrifuges	High cost, mechanically intensive
Stabilization	Anaerobic Digestion	Compatible with land application
	Aerobic Digestion	Compatible with land application
	Thermal Treatment	High cost, odors, mechanical/energy intensive
	Lime Stabilization	Increased solids generated, lime handling
	Facultative Sludge Lagoons	Available land, easy to operate
Dewatering	Drying Beds	Land available, easy to operate
	Drying Lagoons	Land available, easy to operate
	Mechanical Systems	
	Belt Filter Press	Reliable, easy to operate, low energy use
	Centrifuge	Comparatively high in cost, energy, and maintenance
	Vacuum Filter	High energy, mechanically intensive, constant attention required
	Pressure Plate Filter	High cost, batch operation, mechanical/labor intensive
	Drum Screen	Relatively poor performance
	Carver-Greenfield	High cost, mechanically intensive/complexity
	Heat Treatment	Odors, mechanical/energy intensive
Disposal	Landfill	Dependable option to land application
	Land Application	
	Solid	Excellent soil conditioner/fertilizer
	Liquid	Sludge salinity levels high, quantities too large to dispose of
	Offshore	Pollution of water body
	Incinerator	High cost, air emissions, ash disposal problems

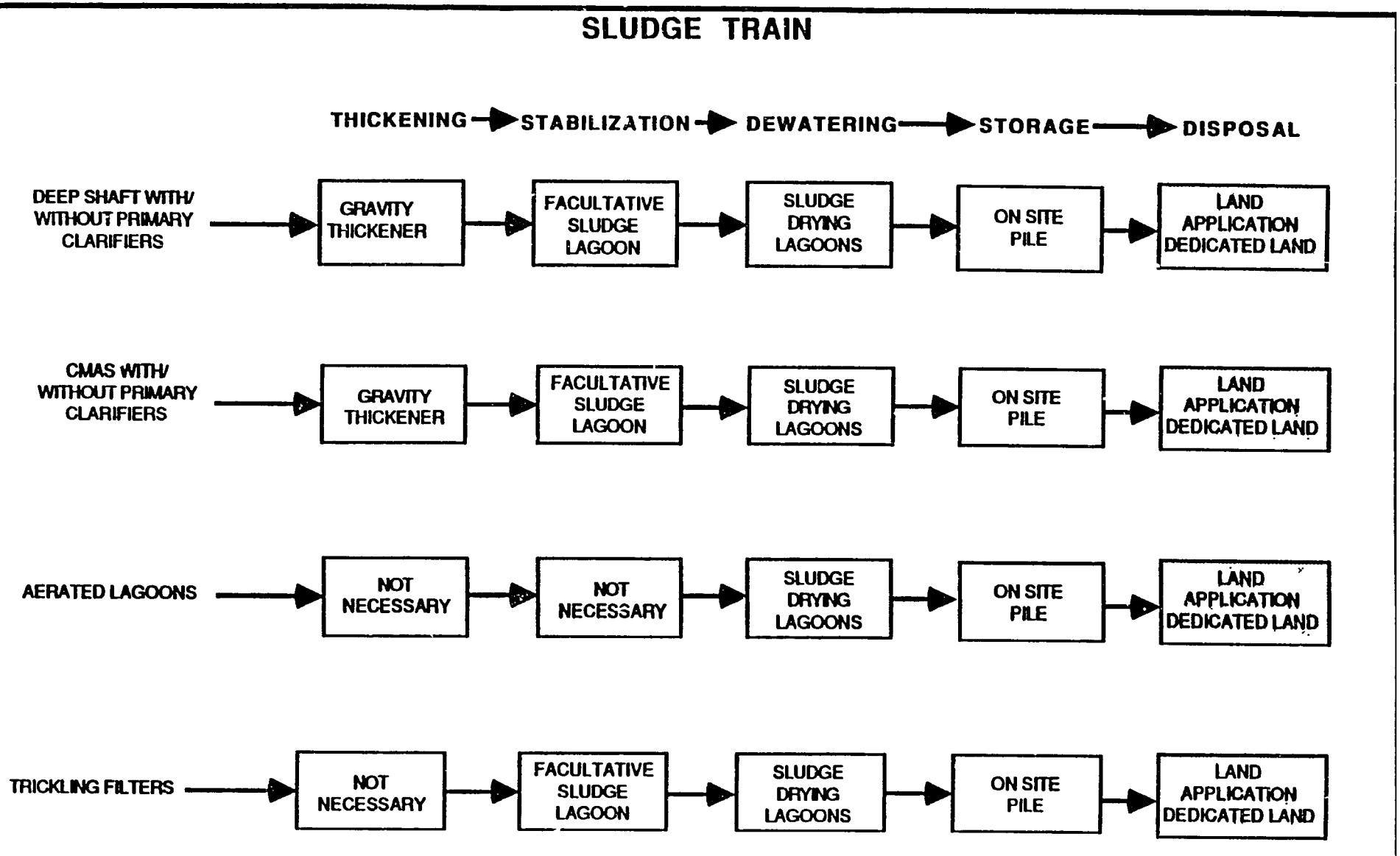


FIGURE 2-5
PROPOSED SLUDGE PROCESS TRAINS
SUEZ

Dames & Moore

Feed Sludge	0.5 - 2% solids
Mass Loading	45 $kg/m^2/day$
Hydraulic Loading	400 $l/m^2/hr$
Thickened Solids	3 - 6 percent

2.7.3.2 Stabilization

Stabilization using facultative sludge lagoons is required for all alternatives except the aerated lagoons. Facultative lagoons maintain an aerobic layer to degrade soluble organic matter. Oxygen is supplied from mixers, surface transfer, or photosynthesis. Mixers keep a scum layer from forming. Solids that settle to the bottom undergo anaerobic decomposition. The design criteria used for this process are as follows:

Feed sludge	0.5 - 4% solids
Area loading	100 kg $VS/m^2/yr$
Volatile solids reduction	20 - 40%
Retention time	9 - 12 months
Depth	4.6 m
Cake solids	6 - 10%
Sludge removal	Dredge or pump

2.7.3.3 Dewatering

Sludge dewatering for all processes consists of drying lagoons. Sludge is placed into the lagoon in cycles. The sludge dries and is naturally dewatered to a predetermined concentration before removal. The predominant dewatering method appears to be evaporation. The design criteria used for this process are as follows:

Feed sludge	0.5 - 4% solids
Net evaporation	4.3 m/yr
Loading rate	62 $kg/m^2/yr$
Max. depth	1 m
Cake solids	20 - 40%
Drying time	2 - 5 months
Sludge removal	Front end loaders

2.7.3.4 Storage and Disposal

Storage and disposal for all treatment alternatives consist of on-site storage and land application on dedicated land on-site. An area of 2 feddans is required for storage and handling. Sludge will be stored for 45 to 90 days. Land application will

be on 250 feddans of land at the west end of the proposed treatment plant site. Approximately 50 metric tons/feddan will be applied annually.

2.7.4 Analysis of Wastewater Treatment Alternatives

Wastewater treatment alternatives were analyzed for capital (construction) costs, O&M costs, and life cycle costs. Capital costs are based on current construction practices and costs in the United States at an Engineering News Record Construction Cost Index (ENRCCI) of 4,597 (July 13, 1989). O&M costs are based on labor costs of $2,400/yr per operator, energy costs of $0.02/kwh, and chemical (chlorine) costs of $575/ton. Present worth costs are based on a period of 10 years, a 30 year life for structures, a 10 year life for equipment, and an interest rate of 8.875 percent. Costs for each alternative are summarized on Table 2-5 along with the advantages and disadvantages of each unit process.

The aerated lagoons have the lowest capital and present worth costs. This process is reliable, easy to operate, and relatively simple. The deep shaft process alternatives have higher capital and present worth costs as compared to the aerated lagoons. This process is more complicated and requires a high degree of operator attention. The activated sludge process alternatives have higher capital and present worth costs than the aerated lagoons. The process is reliable, but requires a high degree of operational monitoring to ensure proper performance. The trickling filter has higher capital and present worth costs but lower O&M costs than the aerated lagoons. The trickling filter is reliable and familiar to the Egyptians, but is more complex than the lagoons.

Based on this analysis the aerated lagoon process was recommended for Suez. The recommendation is based on low capital costs, low present worth cost, high reliability, low maintenance, and simple operation. All other alternatives have higher capital and present worth costs and are more complex. Furthermore, the key to operation of the aerated lagoon system is the vigorous aeration in the complete mix lagoon. Without it, however, the treatment plant will continue to operate as a facultative anaerobic system. Although the quality of effluent would be less than secondary and odor problems may arise, the process is the only one that will continue to treat the wastewater. Thus, it offers the greatest degree of treatment reliability in that it will continue to provide treatment even if the key operational component is not functioning. The preliminary capital costs for this system including sludge treatment is $75,000,000. The preliminary annual O&M cost is $1,600,000; the aerated lagoon system has the highest O&M cost because of the high power demand for the aeration.

Table 2-5. Comparison of Wastewater Treatment Systems.

Treatment Alternative	Capital Cost[a] (10^6)	Annual O&M Costs (10^6)	Present Worth Value (10^6)	Advantages	Disadvantages
Aerated Lagoons	$ 75.00	$ 1.60	$ 77.89	Least cost alternative Least complex to operate High treatment reliability	Requires more land than the other processes
Trickling Filters	86.90	0.99	83.77	Familiar process to Egyptians High treatment reliability Requires less land area than lagoons	More complex to operate than aerated lagoons More expensive than aerated lagoons
Deep Shaft with Primary Clarifiers	106.35	1.28	102.96	Requires less land area than trickling filters	Very high cost Complex to operate Treatment reliability depends on proper operations
Deep Shaft without Primary Clarifiers	98.28	1.25	95.57	Requires least land area	Very high cost Complex to operate Treatment reliability depends on proper operations
Conventional Activated Sludge with Primary Clarifiers	94.57	1.39	93.19	Produces high quality effluent Lower cost than trickling filter	Treatment reliability depends on proper operation
Conventional Activated Sludge without Primary Clarifiers	87.30	1.32	86.24	Produces high quality effluent Lower cost than trickling filter	Treatment reliability depends on proper operation

a: Total cost for treatment alternative and sludge facilities.

2.8 Effluent Disposal Facilities

Effluent from the new plant site will be discharged into Suez Bay. The facilities include a gravity main to Suez Bay and an outfall extending out to the 10-m isobath. Other effluent disposal options that were considered are a shallower outfall (at the 5-m isobath) and discharge directly to the Gulf of Suez. The proposed facilities estimated cost is $18,861,000.

2.9 Other Project Elements

Project elements common to all alternatives have been identified. These items include: administration, warehouse, and maintenance facilities; O&M training materials and assistance; inventory and flow conservation programs; industrial users survey and monitoring, sewer infiltration flow survey; and sewer rehabilitation. Costs for these items are shown in Table 2-6, and total $19,873,000.

2.10 Summary of Recommended Project

The total recommended facilities for Suez are summarized as follows:

1. An influent pump station (Pump Station No. 11) with a design peak flow capacity of 260,000 m^3/d (four 900 l/sec pumps); a 1,200-mm diameter, 1.4-km long force main conveying flow from Pump Station No. 11 to the proposed wastewater treatment plant site.

2. A 1,800-mm diameter, 4.1-km long Southwest Trunk Sewer conveying flow from the existing WWTP to the new pump station.

3. Wastewater treatment units consisting of preliminary treatment followed by three complete mix lagoons with 1 day detention, three partial mix lagoons with 5 day detention, and three polishing ponds with 5 day detention.

4. Sludge processing units consisting of drying lagoons to dry sludge removed from the treatment lagoons and sludge removal equipment; stockpile area to store dry sludge for approximately 90 days; and a sludge disposal site on dedicated land at the west end of the proposed plant site.

5. A 1,500-mm diameter effluent force main from the plant site to a 1,500 mm diameter outfall extending approximately 1500 m from the shoreline into the bay to the 10-m isobath.

Table. 2-6. Costs of Other Project Elements.

	Cost	
	U.S. $	L.E.
Administration Building (600 sq m)	343,000	2,310,000
Warehouse (2,600 sq m)	285,000	7,333,000
Maintenance Building (4,200 sq m)	3,654,000	14,573,000
O&M Manuals Standard Procedures, Videotapes and Mockups	1,677,000	982,000
O&M Assistance	3,790,000	3,430,000
Inventory Control Programs	569,000	515,000
Flow Conservation Program	505,000	457,000
Industrial Users Survey	253,000	456,000
Industrial Waste Monitoring	572,000	518,000
Sewer Infiltration Survey	638,000	578,000
Sewer Rehabilitation	6,380,000	5,775,000
Subtotal	18,066,000	36,927,000
Contingencies @10%	1,807,000	3,693,000
Total	19,873,000	40,620,000

6. Administration, maintenance and warehouse buildings to serve the city's entire wastewater operations and maintenance requirements.

7. Other miscellaneous project elements as described herein in Section 2.9.

The total estimated costs are shown in Table 2-7. The total cost of the proposed project is $145,600,000.

Table 2-7. Summary of Project Costs (US $1,000,000).

Project Element	Project Paper[a]	Proposed Project
Wastewater Treatment	$ 56.7	$ 72.7
Sludge Processing and Disposal	0	2.3
Influent/Effluent Facilities	42.1	25.7
Miscellaneous Project Elements	41.9	33.8
Engineering/Quality Control by Contractor	11.9	11.1
Total	$ 151.8	$ 145.6

a: Breakdown of costs taken from Annex H, page 51 and 52 and escalated to total cost as shown in Table V-1, page 64 of Project Paper.

CHAPTER 3

3.0 EXISTING ENVIRONMENT

3.1 General Geographic Setting

Suez is situated at the northern end of the Red Sea mountains (Northern Etbai Range) which extend as far south as the Abyssinian Highlands. Suez is also located at the northern-most tip of the Red Sea on the Gulf of Suez (Figure 1-1). A coastal plain (averaging 8-15 km wide) flanks the whole length of the eastern side of the mountains from Egypt to Ethiopia. The proposed new wastewater treatment plant at Suez is located on the coastal plain separating Gebel Ataqa, a mountain plateau (el. 871 m), from Suez Bay. The Ataqa limestone plateau is the northeastern corner of the sedimentary rock complex typical of the northern Eastern Desert of Egypt.

Suez Bay is a relatively shallow, circular embayment at the northern end of the Gulf of Suez and the Red Sea (Figure 3-1). Meshal (1967) calculated areas and volumes for the bay as summarized in Table 3-1.

Approximately 8.3 km south of its head, the bay is marked by two headlands, Ras Adabiya on the west and Ras Misalla on the east. A sill of 10 m depth closes the bay, but is cut by a 23 m deep dredged channel (the Newport Rock Channel). The shores of Suez Bay are low and sandy; expanses of fringing reef border the sides of the bay, and numerous small patch reefs are found within the bay. Green Island lies in the middle of the bay.

The city of Suez, Port Tewfiq, and major industries are located along the northern shoreline of Suez Bay; a smaller commercial port (Port Adabiya), a navy facility, a small ship repair yard, and a fishing harbor (Ataqa Harbor) are located along the western shore (Figure 2-1). Port Tewfiq is the commercial port for the city of Suez, and comprises passenger and freight wharves, and ship building and repair facilities.

The Suez Canal enters the bay at its northeastern corner, and has made Suez Bay part of one of the most important commercial shipping routes of the world. In the late 1970's, the Suez Canal was passing approximately 20,000 ships per year (Moursy, 1978). Underwater cables occur in an area along the western shore (Figure 3-1). East of this area, the bay is used extensively as anchorage for ships awaiting passage through the Suez Canal. Several shipwrecks occur in scattered locations in the bay; they have either been abandoned in place or were dumped in shallow water near shore after removal from the canal following the 1967 and 1973 Middle East wars.

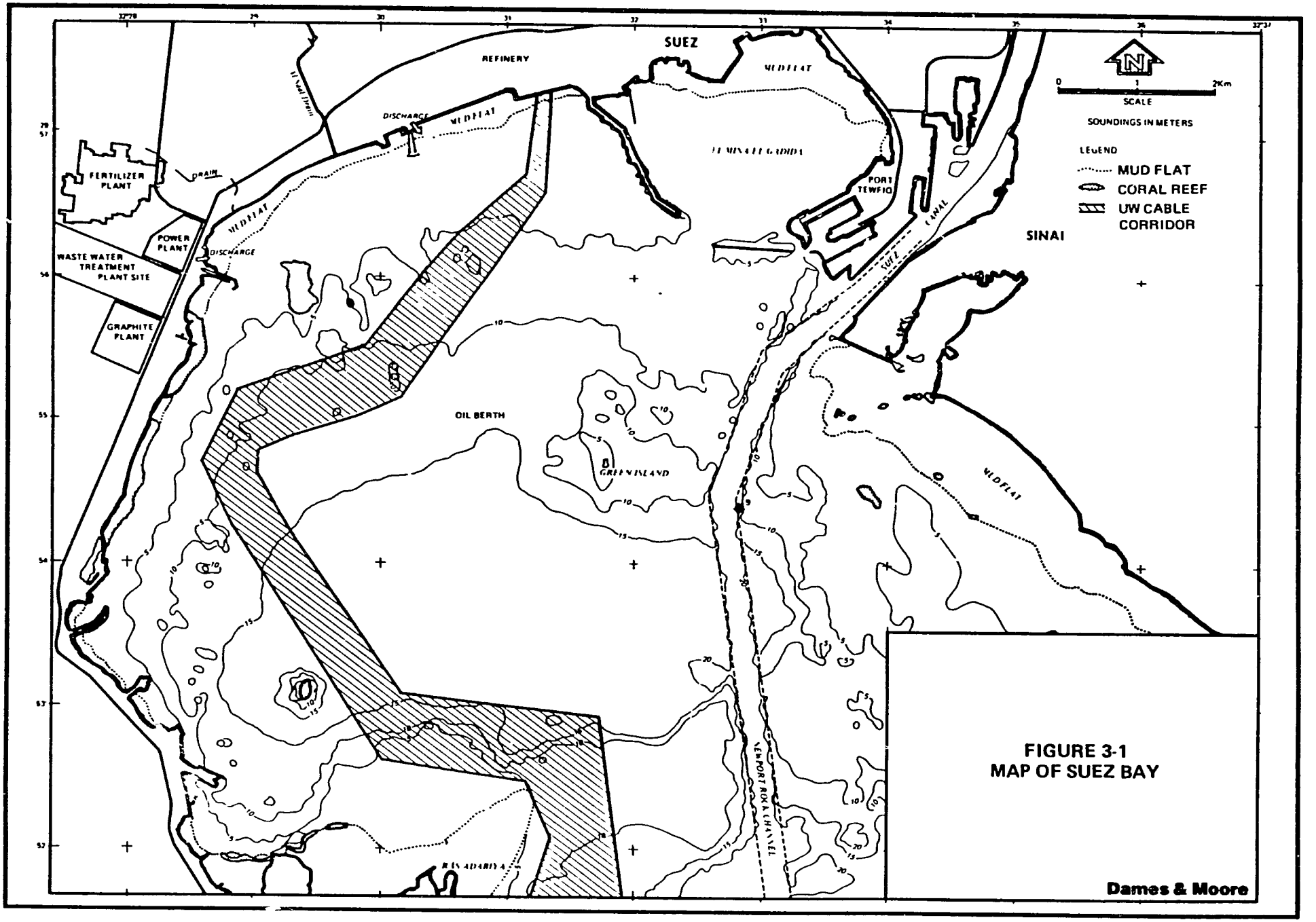


FIGURE 3-1
MAP OF SUEZ BAY

Table 3-1. Area and Volume of Suez Bay.

Length along major axis	13.2 km
Width along minor axis	8.8 km
Mean depth	10 m
Total surface area	77.1 km^2
Area with depth of>2 m	70.1 km^2
Area with depth of>4 m	58.2 km^2
Area with depth of>6 m	52.9 km^2
Area with depth of>8 m	42.3 km^2
Area with depth of>10 m	37.1 km^2
Area with depth of>12 m	31.7 km^2
Volume between 0 and 2 m	0.15 km^3
Volume between 2 and 4 m	0.13 km^3
Volume between 4 and 6 m	0.11 km^3
Volume between 6 and 8 m	0.10 km^3
Volume between 8 and 10 m	0.08 km^3
Volume between 10 and 12 m	0.07 km^3
Volume below 12 m	0.13 km^3
Total volume of Suez Bay	0.77 km^3

Source: Meshal, 1967

An offshore petroleum terminal is located about 3.7 km south of the bay's head in the center of the bay (Figure 3-1). It comprises a loading platform and mooring dolphins, connected to shoreside refineries by submarine product lines.

Several wastewater flows enter the bay and are shown on Figure 3-1. Of primary importance in this investigation is the El Saal Drain which discharges domestic wastewater effluent into the northwestern corner of the bay. It is a surface drain emptying directly into the nearshore zone. Refinery cooling and/or process waters are discharged into the bay approximately 1 km east of the El Saal Drain. About 1.5 km west of the El Saal Drain is another surface drain emanating from a fertilizer plant, and 0.7 km further to the west and south is the intake and adjacent discharge for the recently-constructed power generating station. No complete inventory of discharges into the bay have been made recently; other discharges may be present.

3.2 Climatology and Meteorology

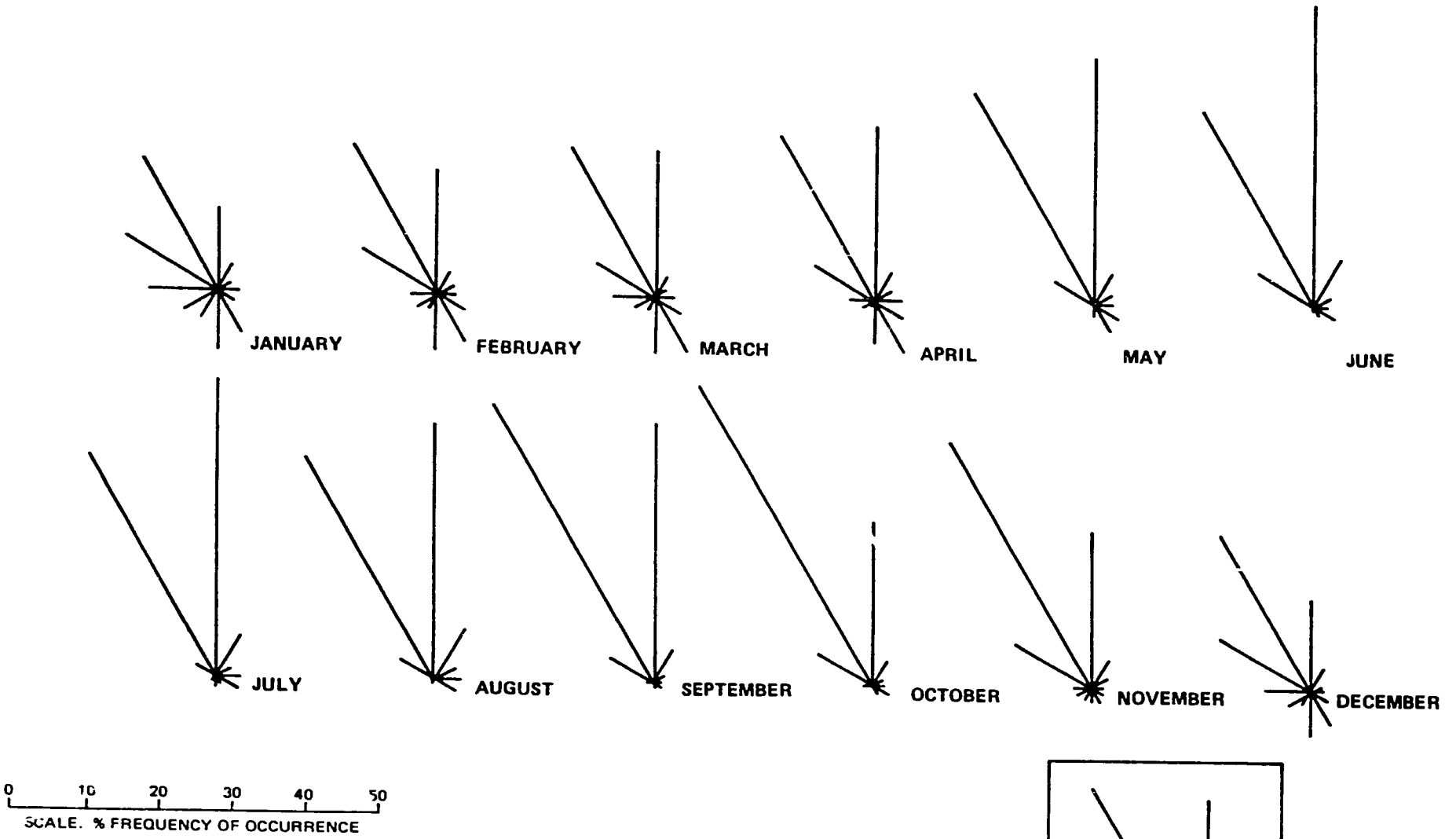
Climatically Suez belongs to a subtropical desert regime which prevails in the region, with a mean temperature of 21.7°C. The mean annual rainfall at Suez is variable, ranging from 2.0 mm (in 1949) to 56.8 mm (in 1952) (Kassas and Zahran 1962). Rainfall is sparse, averaging only 16 mm per year (for the years 1964-1973); most precipitation falls in the form of brief showers during the fall and winter months (October through March). Rainfall is so irregular and unreliable that it is not believed to be a significant factor in any systematic or seasonal fluctuations in ecosystem characteristics (Mancy 1983). Rain is often received in the form of very localized heavy bursts, occasionally causing flash floods to take place in the wadis draining Gebel Ataqa.

North and north-northwest winds predominate in the Suez Bay area throughout the year. Figure 3-2 shows monthly and annual wind roses for Suez for the period 1965-1972; northwesterly winds predominate except for April-August, when northerly winds dominate. About 60% of all winds for that period approached from the sector between 315 and 015°. Southerly and southeasterly winds occur most frequently in the winter months between December and April, but do not exceed about 15 percent of all measurements.

Mean monthly wind speeds are reported (Patzert 1974; El Din 1975) to vary within the range of 2.4-4.4 m/sec (about 5 to 9 knots). Frequencies of occurrences of wind speed during 1965-1972 are shown in Figure 3-3; higher wind speeds occur most frequently during summer months.

Visibility is generally good, with less than 2 days a month experiencing any fog or wind-blown dust.

Figure 3-4 presents a summary of climatic conditions at Suez. Air temperature is highest in August (with daily maxima of about 34°C) and lowest in January (daily



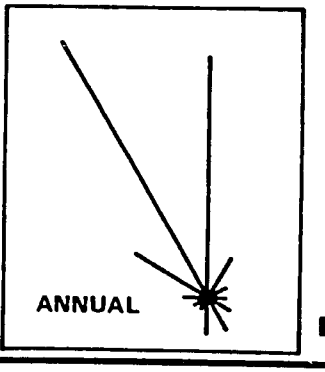


FIGURE 3-2
MONTHLY AND ANNUAL WIND ROSES FOR SUEZ
1965-1972

SOURCE UNPUBLISHED DATA FROM SUEZ CANAL AUTHORITY

Dames & Moore

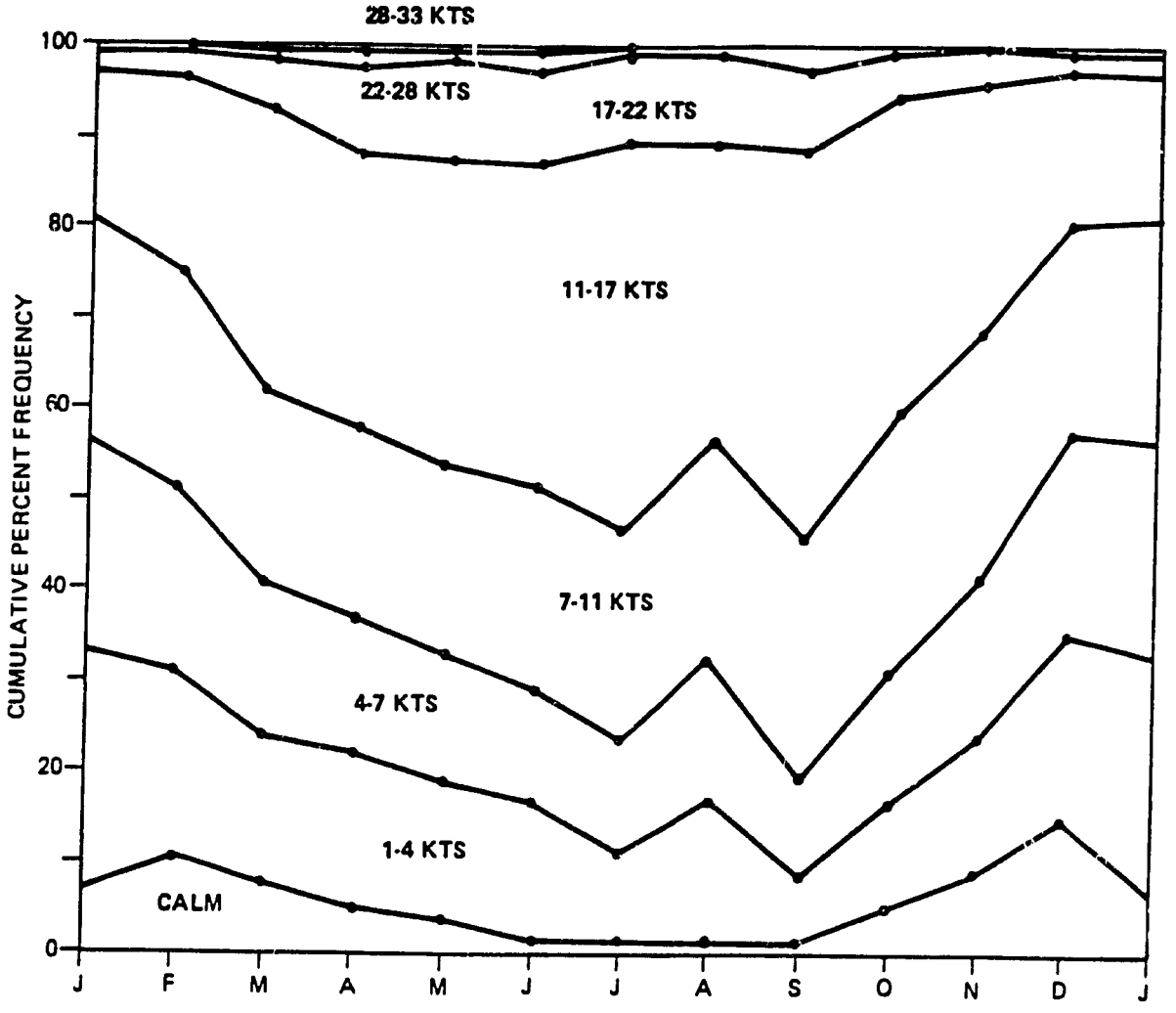
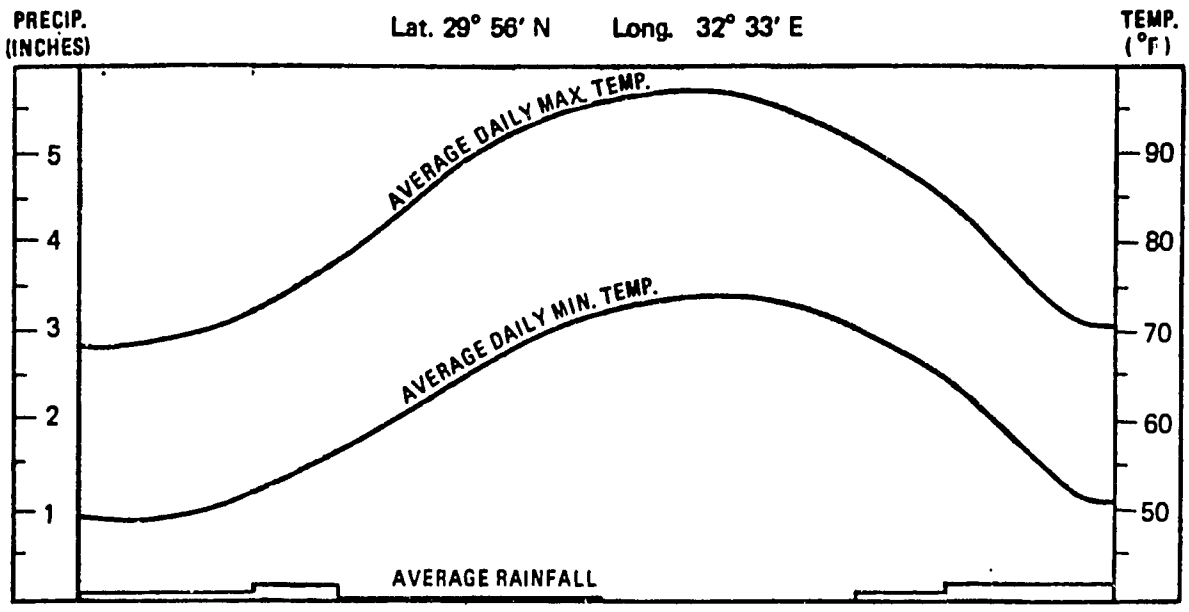


FIGURE 3-3
CUMULATIVE PERCENT FREQUENCY OF OCCURRENCE
WIND SPEED (KNOTS) AT SUEZ BY MONTH
1965-1972

SOURCE UNPUBLISHED SUMMARY DATA SUPPLIED BY SUEZ CANAL AUTHORITY

Dames & Moore



MEAN NUMBER OF DAYS WITH PRECIPITATION, THUNDERSTORMS, FOG

2	1	1	<1	<1	<1	0	0	0	1	1	1
0	0	1	0	0	0	0	0	0	0	1	1
0	0	0	0	0	0	0	0	0	0	1	1

TOTAL PRECIPITATION (INCHES) / MEAN NUMBER OF DAYS WITH DUST

0.1	0.1	0.2	<05	<.05	<.05	0.0	0.0	0.0	0.1	0.2	0.2
1	2	1	1	0	0	0	0	0	1	0	1

MEAN RELATIVE HUMIDITY (PERCENT)

62	62	56	52	49	51	53	57	60	59	61	62

MEAN TEMPERATURE (°F)

59	60	65	71	78	83	8[illegible]	86	81	78	70	61

ABSOLUTE MAXIMUM/MINIMUM TEMPERATURE (°F)

84	88	94	109	111	120	109	109	106	109	106	93
35	37	38	46	51	60	65	66	60	54	45	36

PREVAILING WIND DIRECTION / MEAN SPEED (KNOTS)

N	N	N	N	N	N	N	N	N	N	N	N
5	6	8	9	9	10	10	10	10	8	8	6
JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC

FIGURE 3-4
CLIMATIC CONDITIONS AT SUEZ, EGYPT

SOURCE U.S. NAVAL WEATHER SERVICE COMMAND, 1974b

Dames & Moore

maxima of about 19°C). The difference between daily high and low temperatures are approximately 8-12°C.

Mean monthly relative humidity varies between 49 and 62% (U. S. Naval Weather Service Command 1974b). Evaporation rates are very high; unpublished data provided by the Suez Canal Authority shows that average daily evaporation rates for Suez are greatest in summer (15 mm per day) and lowest in winter (about 7 mm per day). Annual evaporation is estimated to be approximately 4 m per year.

3.3 Physical Oceanography

Most of our knowledge of the oceanography of Suez Bay derives from three studies. The first general examination of the physical character of the bay was done by Meshal (1967; 1970) who investigated physical and chemical parameters in the bay over a 14 month period in 1966 and 1967. Marine Environmental Services (1979) performed a comprehensive one-month field study in support of the Suez Wastewater Facilities Master Plan (Pirnie-Harris International 1979); they collected current and water quality data at 24 stations in Suez Bay and in the adjacent northern end of the Gulf of Suez. A decade later, Dames & Moore (1990) described two field investigations carried out in July and in November-December 1989, also in support of the Suez wastewater treatment facility planning and design. The latest study is presented as Appendix B. Much of the information summarized below is from that report (Dames & Moore 1990) and its accompanying appendices.

3.3.1 Tides and Waves

The mean tidal range at Port Tewfiq (i.e., the difference in height between mean high water and mean low water) is 1.16 m; the spring range is 1.43 m (U.S. National Ocean Survey 1988). Extreme tidal elevations of up to 2.7 m are reported during episodes of southern winds when wind setup raises sea level in Suez Bay (British Admiralty 1955).

The variation in tidal elevation at Suez is affected more by local and regional wind stresses than by atmospheric pressure pattern (Patzert 1972; El Din 1975). There is a maximum of mean sea level at Port Tewfiq in winter and a sharp decrease from May to late summer (Patzert 1974); that variation is well correlated to the seasonal monsoons of the Indian Ocean. Figure 3-5 (El Sabh 1967) shows monthly mean sea levels for Port Tewfiq for the period 1924-1937 and for 1966. El Din (1975) provides analyses of tidal data for an 11-year period (1955-1966) at Port Tewfiq, and shows that mean sea levels there are highest in winter and lowest in late summer, with summer values generally between 30 and 40 cm lower than winter.

No published information exists on the wave regime of Suez Bay. Because northerly and northwesterly winds dominate the entire northern reaches of the Red Sea (including the Gulf of Suez and Suez Bay), little long period wave energy (swell) would

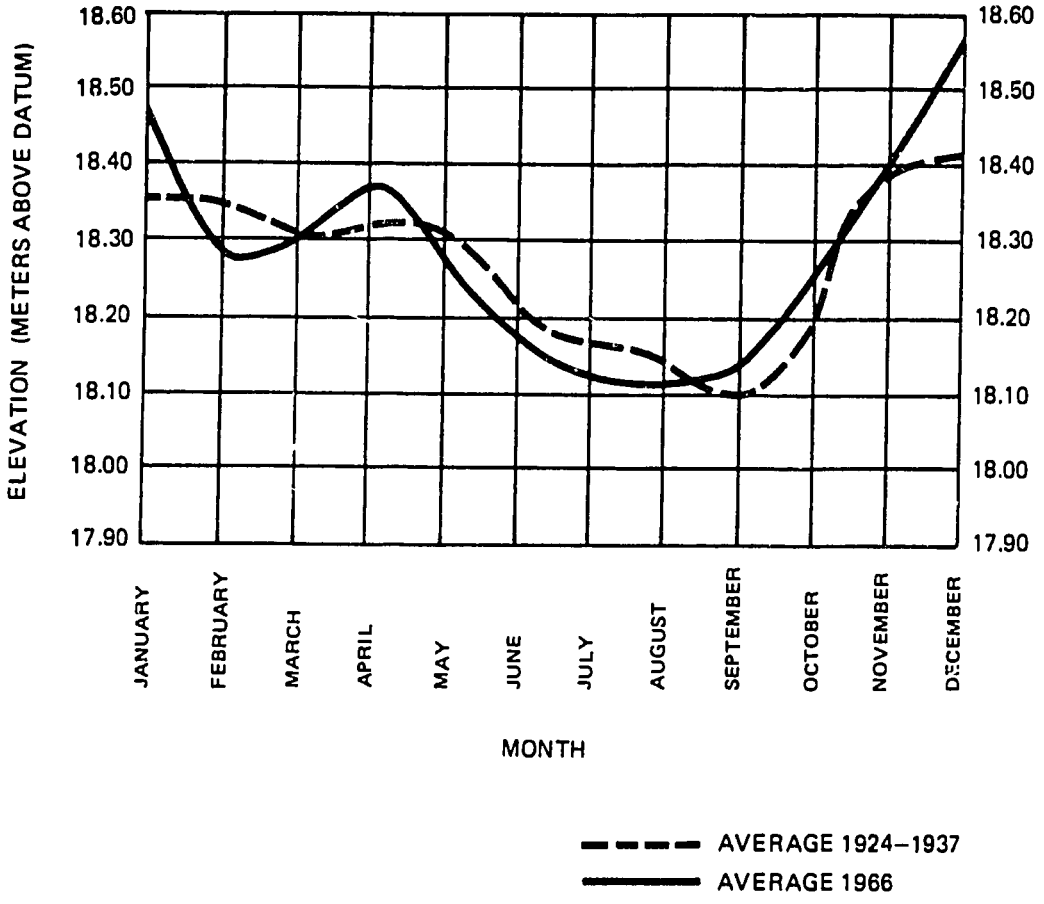


FIGURE 3-5
MEAN MONTHLY SEA LEVEL AT PORT TEWFIQ

SOURCE EL SABH, 1967

Dames & Moore

be expected in the bay. Waves are most likely to be those generated locally (seas), with short periods (< 8-9 seconds). Because of the limited fetch, seas would be expected to be small; for example, a fully developed sea resulting from a 12 m/sec wind blowing over a 13.5 km fetch would be approximately 1 m in height.

3.3.2 Currents and Circulation

The amount of information available on nearshore current and circulation patterns in Suez Bay is limited. Most available current measurements from Suez Bay have been individual profiles taken at infrequent intervals and at widely spaced stations, and are not well suited to describing time-dependent flows at any given location (such as a proposed discharge site). During each of the three oceanographic studies, current flows and long-term circulation patterns have been inferred from direct measurements using current meters and drogues, and from interpretation of water mass characteristics (primarily temperature, salinity, and oxygen concentrations).

Based largely on a limited number of monthly surface current measurements taken from May 1966 to June 1967, Meshal (1967) postulated a persistent counterclockwise (cyclonic) circulation pattern in Suez Bay. The net flow was believed to be superimposed on an oscillatory flow that was related to tidal stage. He found the strongest currents, up to 91 cm/sec, at Port Tewfiq in the entrance to the Suez Canal, and recorded much lower speeds (approximately 10-20 cm/sec) in other parts of the bay.

Marine Environmental Services (1979) suggests that tidal currents are important in the bay, particularly at and near the times of spring tides, and that water masses move northward on rising tides (as measured at Suez) and southward on falling tides. Their interpretations appeared to confirm Meshal's earlier hypothesis that the dominant residual circulation pattern in the bay is a counterclockwise gyre. Importantly, measurements at the Marine Environmental Services Station 3, located about 2.5 km south of the proposed submarine outfall site, suggest a net southerly flow, although reversal to the northwest may occur during spring tides.

The only continuous current meter record presently available is from the one-month deployment period in late 1989 at a location in 5 m water depth off the El Saal Drain (Dames & Moore 1990). The current meter measured subsurface flow at an elevation of -2 m MLLW (mean lower low water). Maximum current speeds measured at that location were very low, never more than 10 cm/sec, and averaged approximately 2 cm/sec (Figure 3-6). There was little evidence of oscillatory tidal currents in that record. Both Figure 3-7, a current rose, and Figure 3-8, a progressive vector diagram, indicate a northerly flow of subsurface waters. A few minor short-term flow reversals are evident in Figure 3-8. The small net easterly flow shown in Figure 3-8 over that one month period, supported by field observations of the movement of the wastewater plume from El Saal Drain, suggest that a secondary clockwise gyre may exist in the extreme northern part of the bay between El Mina El Gadida and the reef lying offshore of the power plant.

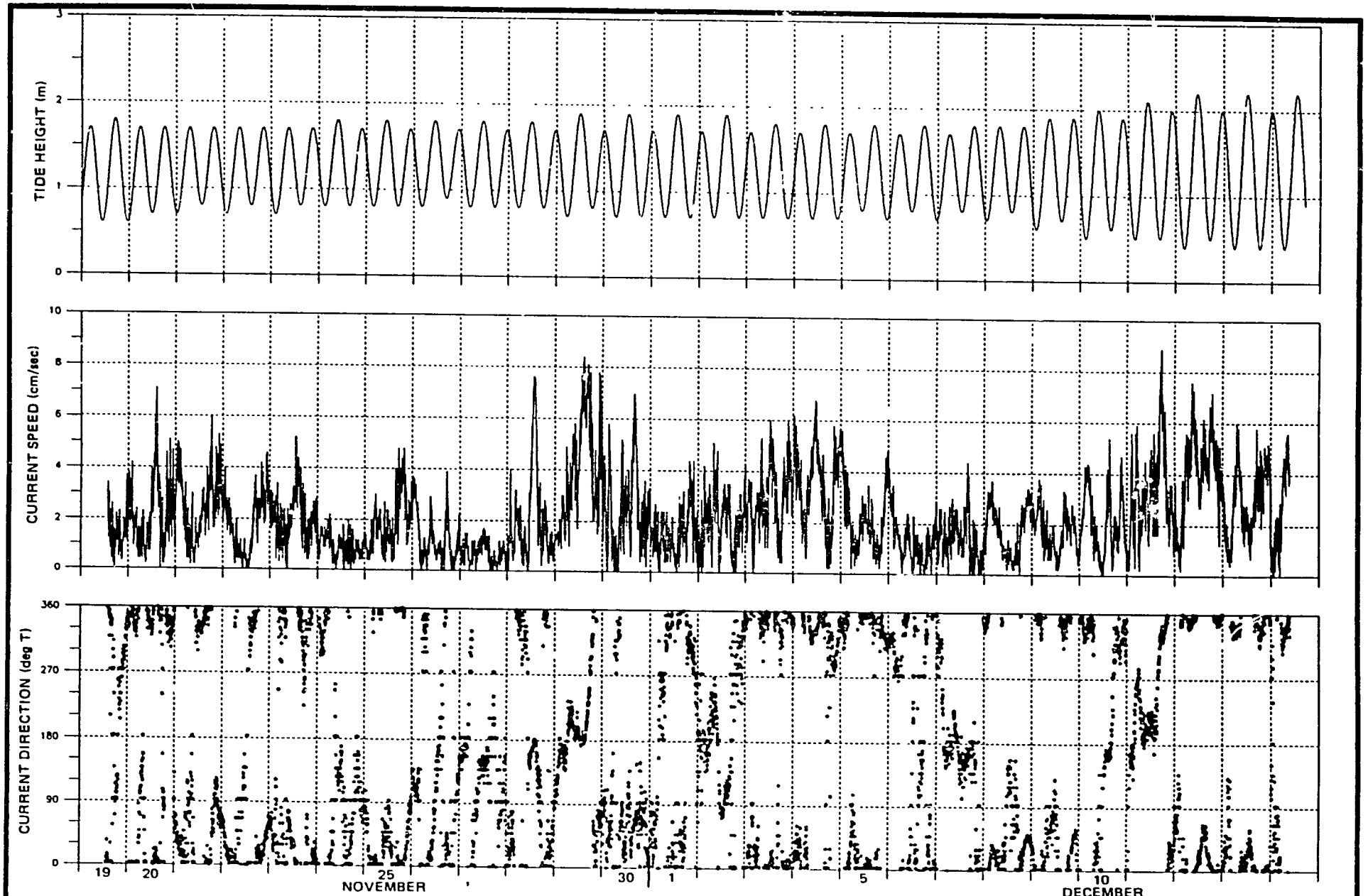


FIGURE 3-6
CURRENT METER RECORDS FROM STATION 5, OFF EL SAAL DRAIN
NOVEMBER-DECEMBER 1989

SOURCE: DAMES & MOORE, 1990

Dames & Moore

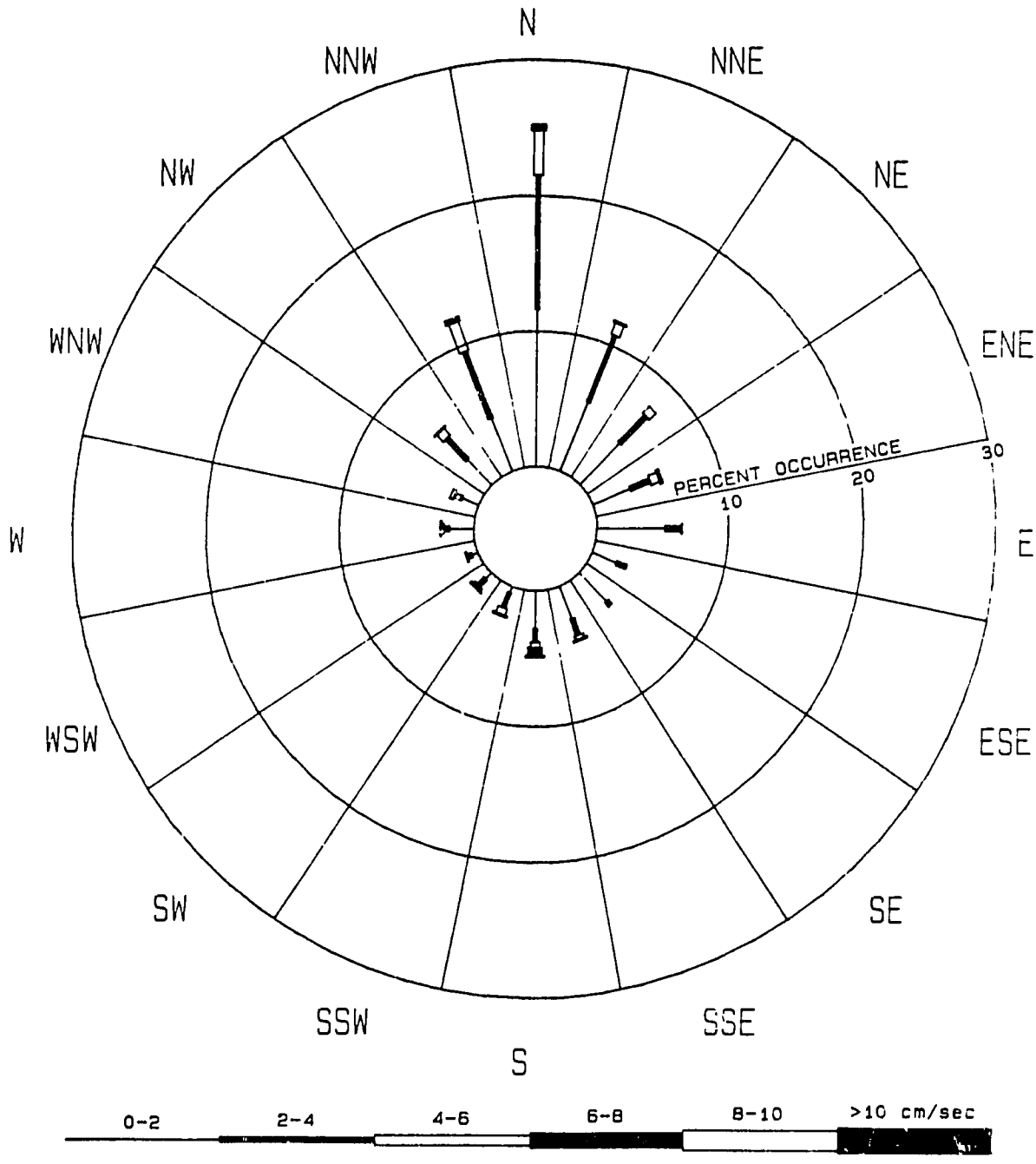


FIGURE 3-7
CURRENT ROSE FOR STATION 5, OFF EL SAAL DRAIN
NOVEMBER-DECEMBER 1989

SOURCE: DAMES & MOORE, 1990

Dames & Moore

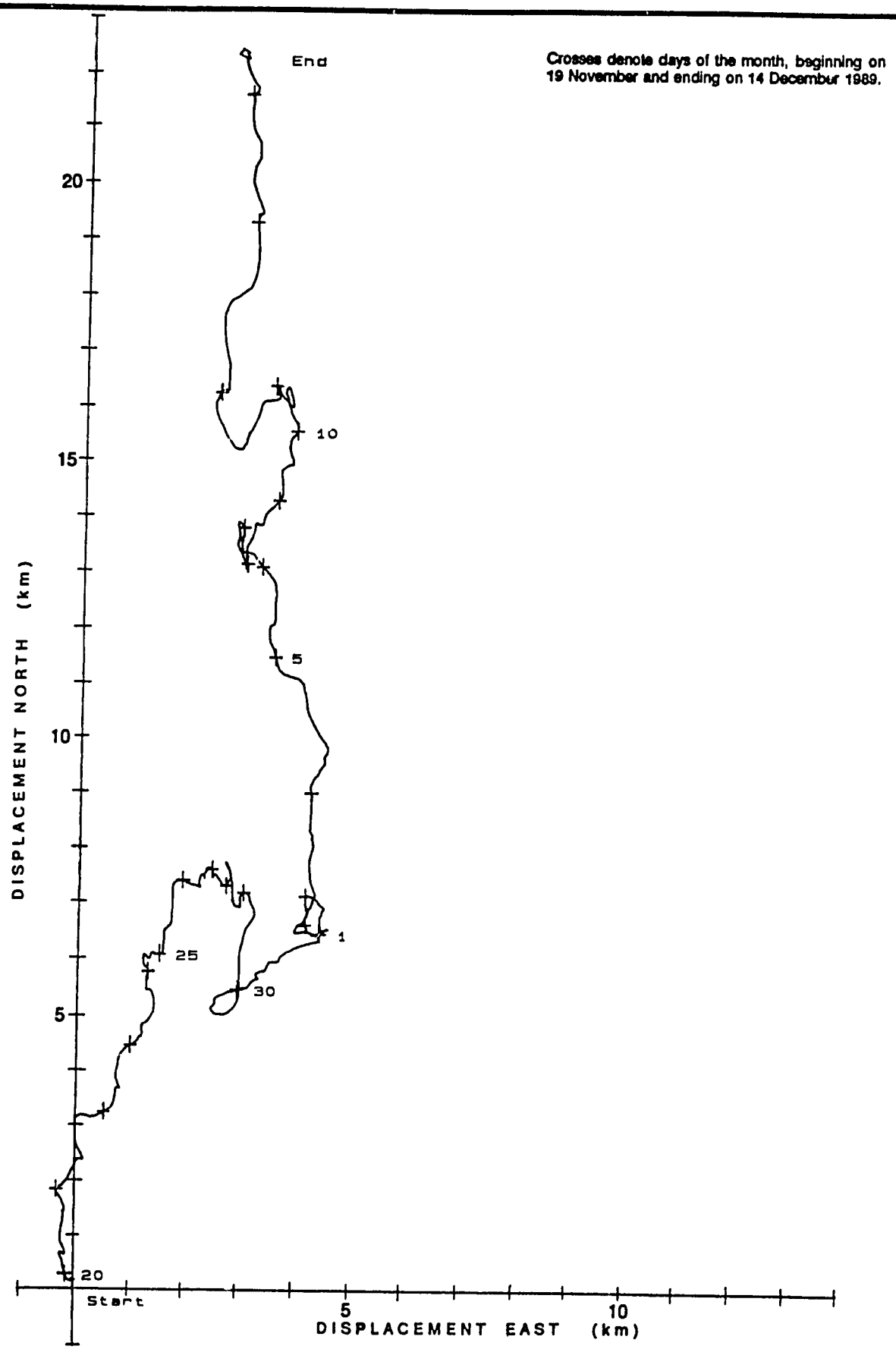


FIGURE 3-8
PROGRESSIVE-VECTOR DIAGRAM
FOR CURRENT AT STATION 5, OFF EL SAAL DRAIN
NOVEMBER-DECEMBER 1989

SOURCE: DAMES & MOORE, 1990

Dames & Moore

Currents in the vicinity of the proposed submarine outfall are known only from a small number of vertical profiles taken during the winter of 1989 (Station 6 of Dames & Moore 1990); those data are overplotted in Figure 3-9. Speeds at the surface are low, between 5 and 20 cm/sec, and usually decreased with depth down to 8-10 m, where they increased dramatically to a maximum of 150 cm/sec (about 3 knots). Flow directions are highly variable (common with such low speeds), but were generally southerly in the upper 5 m of the water column, generally northerly between 5 and 10 m, and then shifted southerly again below 10 m depth. As was the case off the El Saal Drain, surface waters generally moved southward while intermediate subsurface waters flowed northward.

The high speed currents measured at depth at Station 6 were also seen at similar depths in other locations in the bay (the deeper central part, off Green Island, and east of Green Island in the dredged channel). The hydrodynamics of these jets are not well understood, but because of their potential for disruption of underwater construction and for scour around seafloor structures, they need to be considered in engineering design studies.

The conceptual model of the current regime in Suez Bay that derives from the available information suggests that the dominant northwesterly winds move the surface waters southward and southeasterly toward the mouth of the bay, while subsurface waters are drawn into the bay and toward the northern shoreline to replace those waters moved offshore. There is evidence of a net easterly flow of nearshore waters off the El Saal Drain, and a net southerly flow at the site of the proposed submarine outfall.

3.3.3 Water Mass Physical Characteristics

3.3.3.1 Temperature

Mean annual surface water temperature at Suez is about 22°C (Figure 3-10). Generally, the temperature in February is 5°C below the annual mean, and is 5°C higher in August.

Monthly mean temperature values measured by Meshal (1967) agree with those shown in Figure 3-10. Winter surface temperatures measured along the northern and western shores of Suez Bay in January (Marine Environmental Services 1979) ranged from 16.4 to 19.0°C. Surface temperatures measured in July 1989 varied between 25.0 and 26.7°C and decreased only slightly with depth (generally less than 1.0°C). Seawater temperature during the November-December field survey decreased from about 23°C to less than 20°C. All temperature measurements appear to be consistent and indicative of a highly regular seasonal temperature cycle. Suez Bay waters appear to be generally well mixed and unstratified, although Meshal (1967) reports that a significant thermocline develops during the summer months. The July 1989 data (Dames &

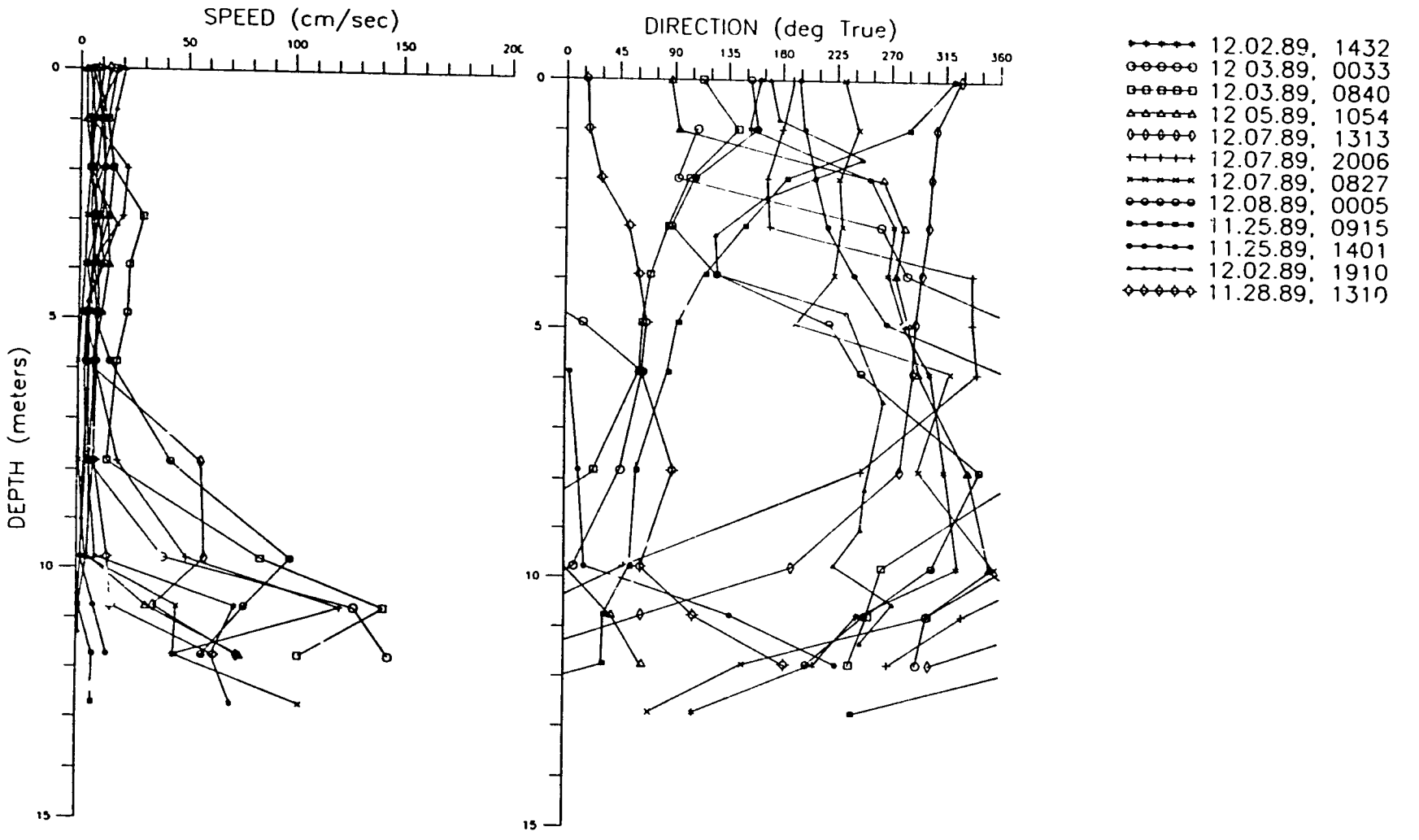


FIGURE 3-9
CURRENT PROFILE DATA FROM STATION 6, NEAR PROPOSED SUBMARINE OUTFALL
NOVEMBER-DECEMBER 1989

SOURCE DAMES & MOORE, 1990

Dames & Moore

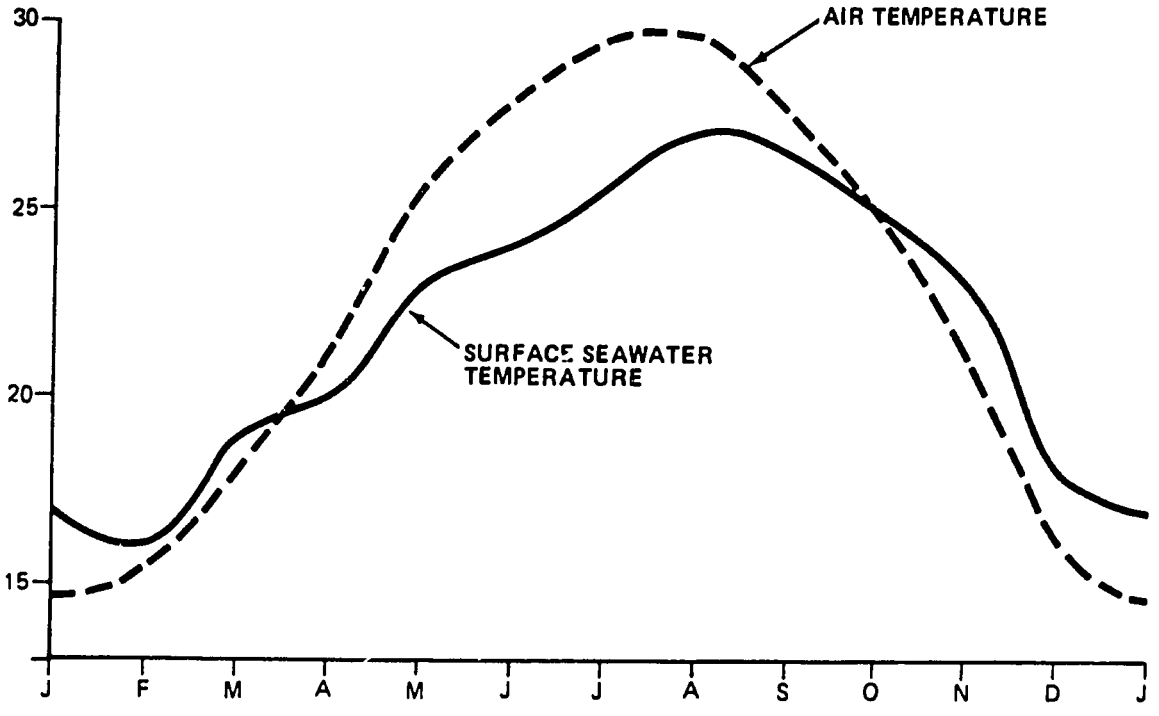


FIGURE 3-10
ANNUAL VARIATION IN MONTHLY AIR AND SEAWATER
TEMPERATURES AT SUEZ, EGYPT

SOURCE DATA FROM MORCOS, 1970

Dames & Moore

Moore 1990) did not indicate presence of a thermocline during the short sampling period.

3.3.3.2 Salinity

The waters of Suez Bay are among the most saline ocean waters found in the world; salinity lies between 42 and 43 parts per thousand (ppt) except in late summer when it slightly exceeds 44 ppt (Morcos and Riley 1966). The cause of the extraordinarily high salinities seen in Suez Bay and the Gulf of Suez is not well understood. Possible explanations that have been advanced are: a) seasonal inflow from the Suez Canal of highly saline waters transported southward from the Great Bitter Lake; b) local evaporation and attendant increase in salinity; and c) partial dissolution of evaporite strata underlying the waters of the bay and gulf.

The upper panel of Figure 3-11 is representative of the annual cycle on salinity. Minimum salinities of about 42.1-42.2 ppt were found at all depths in spring (May) while maxima of 42.7 ppt were found in autumn (October-November). Average salinities measured in Suez Bay and the northern Gulf of Suez in 1979 (Marine Environmental Services 1979) ranged between 41.3 and 42.2 ppt, and were vertically isohaline. Subsurface salinity values measured in late 1989 (Dames & Moore 1990) fell within the narrow range of 42.5 to 42.7 (in agreement with Meshal's 1966-1967 analyses), with the exception of one station lying immediately off the mouth of the El Saal Drain. Surface salinities measured at that station during the recent study exhibit wide variability, and for the first time show a freshwater surface layer in the vicinity of the El Saal Drain.

3.3.3.3 Water Clarity

Light is a major factor in the growth of phytoplankton and the growth and reproduction of attached marine plants. The clarity of Suez Bay waters has been measured using turbidity meters (Marine Environmental Services 1979) and Secchi disc measurements (Marine Environmental Services 1979; Dames & Moore 1990). Due to the absence of river inflow and the low surface runoff, the waters of Suez Bay are generally clear. Water clarity is aperiodically degraded when dredging of the canal suspends fine sediment into the water column (Marine Environmental Services 1979). Average turbidity values measured with a turbidity meter in 1979 were greatest (i.e., clearest water) outside of Suez Bay and were lowest at a station offshore of the El Saal Drain. Secchi disc measurements of extinction depth in 1979 showed greater water clarity (Secchi depths > 5 m to a maximum of 8.9 m) in southern Suez Bay and outside of the bay, and lowest clarity in the shallower waters of the bay.

Secchi disk measurements in late 1989 (Dames & Moore 1990) were confined to the northwestern sector of the bay, but showed similar patterns, i.e., consistently greater clarity in deeper water. Note however, that even at the stations immediately off the El

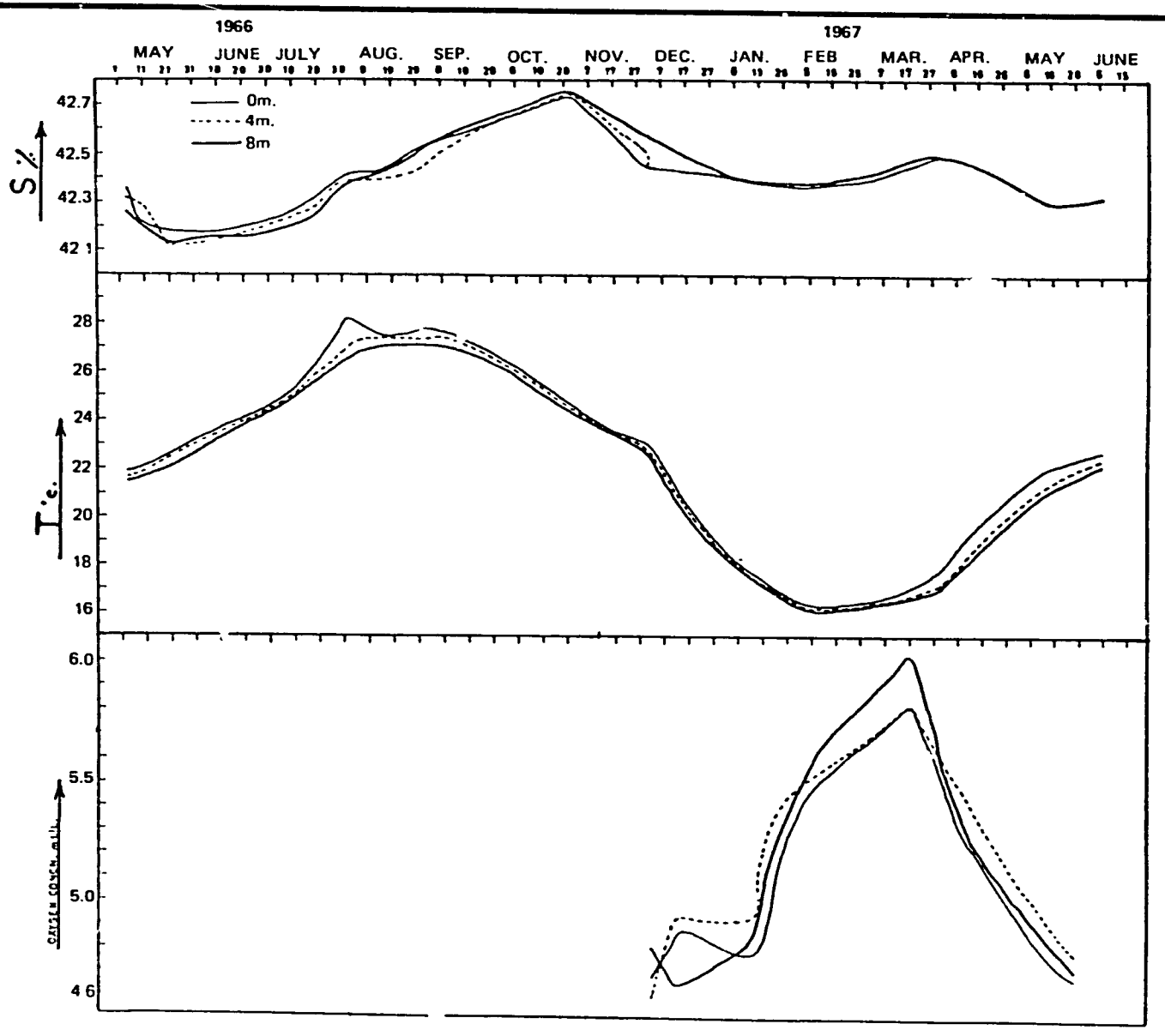


FIGURE 3-11
AVERAGE SALINITY, TEMPERATURE, AND DISSOLVED OXYGEN IN SUEZ BAY
1966-1967

SOURCE: ADAPTED FROM MESHAL, 1967

Dames & Moore

Saal Drain, Secchi depths equaled water depth and the seafloor was generally visible from the surface.

3.3.4 Gulf of Suez

The Gulf of Suez, an arm of the Red Sea, is a relatively long body of water that extends in a southerly direction into the Red Sea. It contains maximum water depths of 40 m. The physical oceanography of the gulf was studied in 1979 by Pirnie-Harris International. The gulf is an open coastal environment with a moderate to strong circulation flow, in contrast to Suez Bay. Circulation patterns are driven by tides, currents, and wind, with the resulting circulation flow proceeding in a clockwise direction at the head of the gulf.

Hydrodynamic studies conducted for Pirnie-Harris International (1979) found ebb and flood tidal velocities in the range of 10 cm/sec, compared to 5 cm/sec in Suez Bay, with average circulation velocities of 6 cm/sec in the gulf operating in a northeast clockwise direction. By contrast, circulation velocities in the bay were less than 4 cm/sec. Plume modeling of proposed gulf discharges in 1979 found greater mixing and dilution due to greater depths and the higher tidal and circulation velocities. The 1979 study concluded that the Gulf of Suez could sustain discharge of a primary treated effluent.

3.4 Water Quality

3.4.1 Pollutant Sources

Suez Bay receives sewage and refuse from both the city of Suez and from ships awaiting transit through the Suez Canal. The bay also receives waste effluents from industrial complexes located along the northern and western shores of the bay, including oil refineries, a fertilizer plant, and other small industries. Industrial wastewater from the major factories and refineries is not discharged to the wastewater collection system (Sayih, pers. comm.). The main pollution problem appears to be oil pollution (Moursy 1978; Mancy 1983), although waste discharges from the fertilizer plant and oil refineries also may be major pollutant sources.

Pollution sources are conveniently divided into point (discrete) sources, such as outfalls and drains, and nonpoint (diffuse) sources such as land runoff or atmospheric fallout of particulates.

3.4.1.1 Point Sources

No current inventory of the sources, character, and magnitude of pollutant sources is available. Meshal (1967; 1970) reported the flow volumes and characteristics of discharges to Suez Bay that occurred at that time; these are summarized in Table 3-2.

Point sources in existence in 1989 include the Suez Company for Petroleum Products, El Ta-awen Refinery, and Misr Petroleum Company; a fertilizer plant; and a power generating station. The kraft mill reported by Meshal is now closed. Domestic and industrial wastewaters enter the bay via the El Saal Drain and other surface drains as well as an underwater pipe from the fertilizer plant. The oil berth in the north central part of the bay may contribute substantial amounts of leaked and spilled petroleum products. The ship repair yards in Port Tewfiq probably contribute heavy metals (from antifoulant bottom paints) and oil and grease. The power generating station may contribute chlorine or other biocides from biofouling treatments of the seawater exchange system used for cooling. Slaughterhouses are probably sources of high BOD loading in the new harbor area.

3.4.1.2 Nonpoint Sources

Possible nonpoint sources of pollutants entering the bay include: a) oily material and refuse from the shipping traffic passing through the Suez Canal or lying at anchor in Suez Bay, b) particulates entering the bay via atmospheric fallout from land-based sources such as automobile exhausts or refinery emissions, c) surface runoff of land-based pollutants during the infrequent rainfall events, d) vessel antifoulant paints and sacrificial anodes, and e) advective transport of water masses from other sources outside of the bay. The Suez Canal Authority is responsible for enforcing regulations prohibiting discharge of wastes from ships traveling through the Suez Canal and Suez Bay.

Chronic oil pollution is a long-recognized problem in Suez Bay (Meshal 1970; UNESCO 1976; El Awady 1981; Awad et al. 1983; El Samra et al. 1983; Mancy 1983; Ferguson 1983). Oil slicks on the surface of the bay were common in 1989 (Appendix B), and have been observed and noted by most other researchers who have worked in the bay. Surface oils will alter the air-water gas exchange (oxygen, carbon dioxide), suppress evaporation, alter water viscosity, and have direct toxic effects on plankton and other biota.

The entire foreshore area between Ataqa and Port Tewfiq was observed in 1989 to be contaminated with oil and tar. The source of these contaminants is not known, but is suspected to be the El Saal Drain and other nearby drains, rather than offshore sources (the oil berth or ships) because the predominant winds will blow surface slicks away from shore.

Table 3-2. Pollutant Discharge to Suez Bay, 1970.

Source	Carrier	Volume (m^3/hr)	Oil (ppm)	Total hardness	Ca hardness	NaCl (ppm)	TDS (ppm)	NO_3 (ppm)	NH_3 (ppm)
Fertilizer Co.	fresh water	500	0	760	500	600	1200	130	50
Suez Petroleum Co	saline water	10,000	40	0	0	0	0	0	0
Al-Nasr Petroleum Co.	saline water	10,000	35	0	0	0	0	0	0
Misr Petroleum Co.	saline water	1,000	35	0	0	0	0	0	0
Kraft Co.	fresh water	150	0	NA	NA	NA	NA	NA	NA
Domestic drainage	fresh water	2,000	NA	NA	NA	NA	NA	NA	

NA - data not available
Source: Meshal 1967, 1970

3.4.2 El Saal Drain

The El Saal Drain enters the northwestern corner of Suez Bay and carries the entire effluent output of the existing wastewater treatment plant as well as raw sewage collected and passed by the treatment plant. The chemical characteristics of the influent to the existing wastewater treatment plant (i.e., the collected wastewaters entering the plant) reported in December 1989 are as summarized in Table 3-3.

Samples of the wastewater stream were collected at the coastal road bridge (about 500 m upstream of the point where the El Saal Drain enters Suez Bay) during the 1989 studies and analyzed for some of the same parameters as the influent sewage described above (Appendix B). A comparison of the influent values for BOD, COD, ammonia-nitrogen, and total phosphorus and corresponding effluent values for July 1989 (average of 2 samples) and November-December 1989 (average of 6 samples) as measured at El Saal Drain is given in Table 3-4.

The sudden increase in BOD_5 concentration in the El Saal Drain in November-December 1989 may be due to large quantities of oil and solid waste observed in the drain near the sampling point. Further investigation in February 1990 revealed an apparently recent oil spill located a short distance upstream of the sampling point. This may have been the source of oil and a factor in the sharp rise in BOD_5 in the last sampling period. Just a few meters downstream of the sampling point, pipelines crossing El Saal Drain near the water surface level tended to trap floating garbage and other solid wastes. This oil-coated material in the vicinity of the sampling station may also have raised the BOD_5 concentration.

Flow from the El Saal Drain appears to be pulsed and is correlated with tidal elevation in the nearshore receiving waters (Dames & Moore 1990). When tides are high, outflow to the bay (as measured at the coastal road bridge 500 m upstream from the mouth of the drain) is diminished; conversely, when tides are low, outflow is increased. Because the effluent waters are relatively fresh, and therefore much less dense than bay waters, the discharge spreads out over the surface of the receiving waters and forms a lens of fresh water that thins with increasing distance from the drain. The lens is visually discernible, primarily because of its high particulate matter content, and was observed during the winter 1989 survey at distances up to 2 km south of the outlet (Dames & Moore 1990). The lens was also discernible by its odor and with salinity measurements.

3.4.3 Suez Bay

Meshal (1967, 1970) was one of the first to document and publish water quality data for Suez Bay. Since his work in the 1960's, water quality data for Suez Bay derives almost exclusively from two investigations. The first is the one-month study done in January 1979 by Marine Environmental Services (1979), and the second is the two-part field survey done in July and November-December 1989 by Dames & Moore (1990). The main text of the latter is incorporated in this EA as Appendix B. Both

Table 3-3. Chemical Characteristics of Raw Sewage in Suez.

Total dissolved solids (TDS)	5300
Suspended solids (SS)	400
Volatile suspended solids (VSS)	140
Biochemical oxygen demand (BOD_5)	280
Chemical oxygen demand (COD)	510
Alkalinity	330
Hardness	1060
Oil and grease	60
Ammonia nitrogen	40
Phosphorus	9
Calcium	200
Magnesium	120
Sodium	410
Potassium	60
Chloride	1210
Silica	3
Sulfate	540
Sulfide	6
Cadmium	0.05
Copper	0.5
Iron	0.3
Lead	0.2
Mercury	0.03
Nickel	0.09
Zinc	0.4

Note: All values in mg/l.

Table 3-4. Chemical Characteristics of Water Samples from El Saal Drain.

	Raw Sewage	El Saal Drain	
		July 1989	Nov - Dec 1989
BOD	280	116	747
COD	510	375	1071
Ammonia-nitrogen	40	0.6	3.7
Total phosphorus	9	4.4	4.0

investigations were done in support of the Suez wastewater treatment facilities siting and preliminary design process. (In comparing reported mean values from these two studies, it should be borne in mind that the 1979 sampling stations were distributed throughout the bay and the northern Gulf of Suez, while most stations in the 1989 surveys were concentrated around the existing and proposed discharge sites in the northwestern section of the bay.)

3.4.3.1 Dissolved Oxygen

Suez Bay seems to be generally well oxygenated throughout the water column, with only slight variations with depth. Concentrations often exceed saturation values.

Meshal (1967) measured dissolved oxygen (DO) concentrations in the bay during monthly cruises from November 1966 to May 1967; average surface DO values over that time ranged from 4.58 to 5.81 mg/l and average values at a depth of 8 m were 4.70 to 6.2 mg/l. DO concentrations were inversely related to seawater temperature, with DO maxima in late winter when temperatures were at their minimum (Figure 3-11).

Surface DO values measured in early January 1979 (Marine Environmental Services 1979) ranged from a low of 4.7 to a high of 6.4 mg/l, corresponding to about 60 and 88 per cent saturation, respectively. Measurements taken as part of the same investigation later in January and in early March 1979 showed somewhat higher values; average values at those times ranged from 6.6 mg/l (89% saturation) to 7.7 mg/l (109% saturation).

DO measurements taken in July 1989 (Dames & Moore 1990) when water temperatures were approximately 26°C were high, between 5.4 and 7.1 mg/l, and fairly uniform with depth; the lower values were found near the El Saal Drain discharge. These concentrations represent saturation values between 90 and 118%, indicating well-oxygenated waters with good vertical mixing. Lower values near El Saal Drain probably indicate impacts of the wastewater BOD on the nearshore environment.

Typical DO concentrations measured in November-December 1989 (Dames & Moore 1990) ranged from about 3.3 to 9.0 mg/l; again, values tended to be lower near the El Saal Drain and higher at stations farthest from the drain.

Available data on DO in Suez Bay waters indicate a well mixed water body with ample oxygen concentrations. DO data, however, are sparse for the summer months, when higher water temperatures will result in lower oxygen concentrations.

3.4.3.2 Biochemical Oxygen Demand (BOD)

BOD_5 determinations were made on Suez Bay waters during the summer and winter 1989 field surveys; no measurements were made during the Marine

Environmental Services (1979) investigation. Summer BOD_5 values ranged from 3 mg/l for stations in the offshore parts of the bay to 16 mg/l in the nearshore area immediately off the El Saal Drain discharge point. Winter stations means ranged from 6 to 12 mg/l, with the higher value recorded at the station nearest the El Saal Drain (Dames & Moore 1990). These data indicate generally low BOD_5 in Suez Bay. BOD_5 loading from El Saal Drain is detectable within 500-1000 m of the outlet, but these and DO values do not indicate significant adverse problems with oxygen levels in the water column in the nearshore zone (i.e., those likely to kill fish and other organisms in the water column).

3.4.3.3 Nitrogen and Phosphorus

Nitrogen compounds that have been measured in Suez Bay waters include ammonia (NH_3), nitrate (NO_3), and total Kjeldahl nitrogen (TKN); phosphorus compounds include orthophosphate (PO_4) and total phosphorus (TP). Of these, ammonia nitrogen is most toxic in its un-ionized form.

Ammonia-nitrogen values measured in 1979 ranged from <0.55 mg/l (the presumed detection limits of that analysis) to 1.68 mg/l; most readings were below detection limits. Values determined during the summer 1989 survey varied between 0.01 and 0.35 mg/l, with no apparent relation between station location and ammonia concentration. Winter 1989 values ranged between 0.05 and 2.4 mg/l and averaged 0.51 mg/l. The usual range for total ammonia-nitrogen in sea water is between 0.001 and 0.05 mg/l (Johnston 1976). At temperature and pH ranges noted in Suez Bay, up to 1.2 - 5.0% of the ammonia is expected to be in the more toxic un-ionized form (Trussell 1972). Although little data are available on toxicity of ammonia to marine species, the small amount of data available suggests that marine species are more tolerant than freshwater species. The values noted at Suez Bay approach those limits established in the US for freshwater species (EPA 1986b).

Nitrates measured in 1979 ranged from <0.15 mg/l to 0.64 mg/l, again with most values below the presumed detection limit of 0.15 mg/l. Station means from the summer 1989 study were between 0.05 and 0.17 mg/l, and from the winter 1989 study between 0.03 and 0.05 mg/l.

TKN values from the summer 1989 field survey ranged from 0.1 to 0.7 mg/l and averaged 0.41 mg/l; winter 1989 values ranged from 0.1 to 8.4 mg/l and averaged 1.23 mg/l.

Orthophosphorus was detected in only two out of 43 samples analyzed in the 1979 study (values equal to 0.004 and 0.010 mg/l). The range of summer 1989 PO_4 values was 0.01 to 0.11 mg/l with an average of 0.01 mg/l; corresponding PO_4 values for winter 1989 analyses were 0.05 to 2.20 mg/l and 0.05 mg/l. Total phosphorus values in 1979 ranged from below detection limits to 0.07 mg/l, with an average of 0.026 mg/l. TP ranged from 0.01 to 0.08 mg/l in summer 1989 and from 0.05 to 1.60 in winter 1989; corresponding average values were 0.023 and 0.115 mg/l.

These data indicate little change in nutrient levels in Suez Bay over 10 years, and seasonal fluctuations may be larger than long-term changes. The data, however, are sparse.

3.4.3.5 pH

Determinations of pH were made on Suez Bay and Gulf of Suez waters in 1979 and again in 1989 (Marine Environmental Services 1979; Dames & Moore 1990). Values in 1979, taken mainly away from shore and outside the bay, ranged between 8.1-8.3, with no anomalies noted; pH values in 1989, most taken from surface water within 3 km of the El Saal Drain, ranged from 7.5 to 8.0. Generally, pH values are not expected to change significantly in marine waters because of the ocean's vast buffering capacity. Lower values near El Saal Drain probably represent data from the less saline surface layer generated by El Saal Drain.

3.4.3.6 Chlorophyll a

Dissolved oxygen levels during daylight hours can be increased by algal photosynthesis. Phytoplankton biomass can be estimated by measuring the amount of chlorophyll in seawater samples. Measurements of chlorophyll a within Suez Bay made during the winter 1979 study ranged between 0.61 and 4.95 micrograms per liter (ug/l) and averaged 2.0 ug/l. Average station values measured during the July 1989 survey varied between 1.6 and 4.8 ug/l and averaged 3.1 ug/l. The higher values in 1989 were believed to be attributable to differences in sampling locations; most of the 1989 samples were collected near the El Saal Drain, where nutrient enrichment may result in higher phytoplankton biomass and higher chlorophyll a concentrations. Chlorophyll a concentrations were also measured during the winter 1989 field study, station averages varied between 1.2 and 3.3 ug/l and the average of all values was 1.9 ug/l. Again, most of the stations in the winter 1989 study were near the El Saal Drain discharge. The data, although sparse, suggest lower phytoplankton biomass in the winter and perhaps slight increases around El Saal Drain.

3.4.3.7 Microbiology

Fecal coliform bacteria (primarily *Escherichia coli)* are commonly used as indicator organisms for evaluating the presence of several enteric pathogens in waters, including bacteria, viruses, protozoa, and other parasites. Total coliform and fecal coliform measurements of Suez Bay seawaters were taken in 1979, and fecal coliforms were analyzed in 1989. Total coliform counts in 1979 were low at all stations, ranging between 2 and 1000 Most Probable Number per 100 milliliters (MPN/100ml) and averaging 100 MPN/100ml. Fecal coliform values in 1979 never exceeded 50 MPN/100ml and usually were non-detectable.

Fecal coliform counts were significantly higher in both summer and winter 1989 surveys, ranging between 500 and 1000 MPN/100ml in summer and between 10 and 11,210 MPN/100ml in winter. The average of all values from the summer survey was 765 MPN/100ml and from the winter survey was 1780 MPN/100ml.

Bacteriological analyses of seafloor sediments near El Saal Drain were conducted in December 1989 for long-lived amoebic cysts indicative of sewage contamination. The distribution of amoebic cysts in sediments showed a pattern of positive test with distance from El Saal Drain (Figure 3-12). The persistent northward flow of subsurface waters seen at Station 5 offshore of El Saal Drain (Dames & Moore 1990) may account for the northward deflection of the isopleths directly offshore of the drain. The amoebic cyst data, in combination with the current data collected as part of the study, suggest that a majority of the settleable fractions of the wastewater discharge from El Saal Drain move eastward, toward the new harbor area.

3.4.3.8 Petroleum Hydrocarbons

The oil and grease content of Suez Bay waters was measured in 32 samples during the summer 1989 field survey. Resulting values averaged 23 mg/l and ranged from 6 to 94 mg/l; highest values occurred most often in the central part of the bay (near the oil berth) rather than near shore. As noted in Section 3.4.1, extensive oil pollution along the shore near El Saal Drain was noted in November-December 1989.

El Samra et al. (1983) reported petroleum hydrocarbon values in sediments from the southern end of the Suez Canal at Port Tewfiq to be 0.04 mg/kg dry weight. Beltagy and Moussa (1984) determined the amounts of organic carbon and organic nitrogen in bottom sediments of the Gulf of Suez, including two samples from Suez Bay. They found that despite the inflow of nutrients into Suez Bay, values for organic carbon (0.551 and 0.486%) and N (0.112 and 0.052%) are similar to those found elsewhere in the gulf. Low C:N ratios were cited as evidence that oil pollution in Suez Bay does not significantly affect organic carbon content, and that added organic matter is nitrogen rich. This suggests that the sewage discharge to Suez Bay may be an important source of organic enrichment of the sediments, but that the level of enrichment is not much different than that found in the Gulf of Suez.

3.4.4 Gulf of Suez

In comparison with Suez Bay, the adjacent Gulf of Suez provides a deeper and more exposed coastal region with greater mixing and assimilative capacity. The Gulf is a relatively shallow (maximum depths of about 40 m) flat-bottomed basin, but with much greater water volume and ability to dilute and disperse wastewaters than Suez Bay. Measured current speeds were slightly more energetic than in Suez Bay (Pirnie-Harris International 1979), but were still low (approximately 10 cm/sec); directions were reported to be essentially north-south for tidal components, with a clockwise residual circulation. Drogue studies showed northerly drift of subsurface waters under both

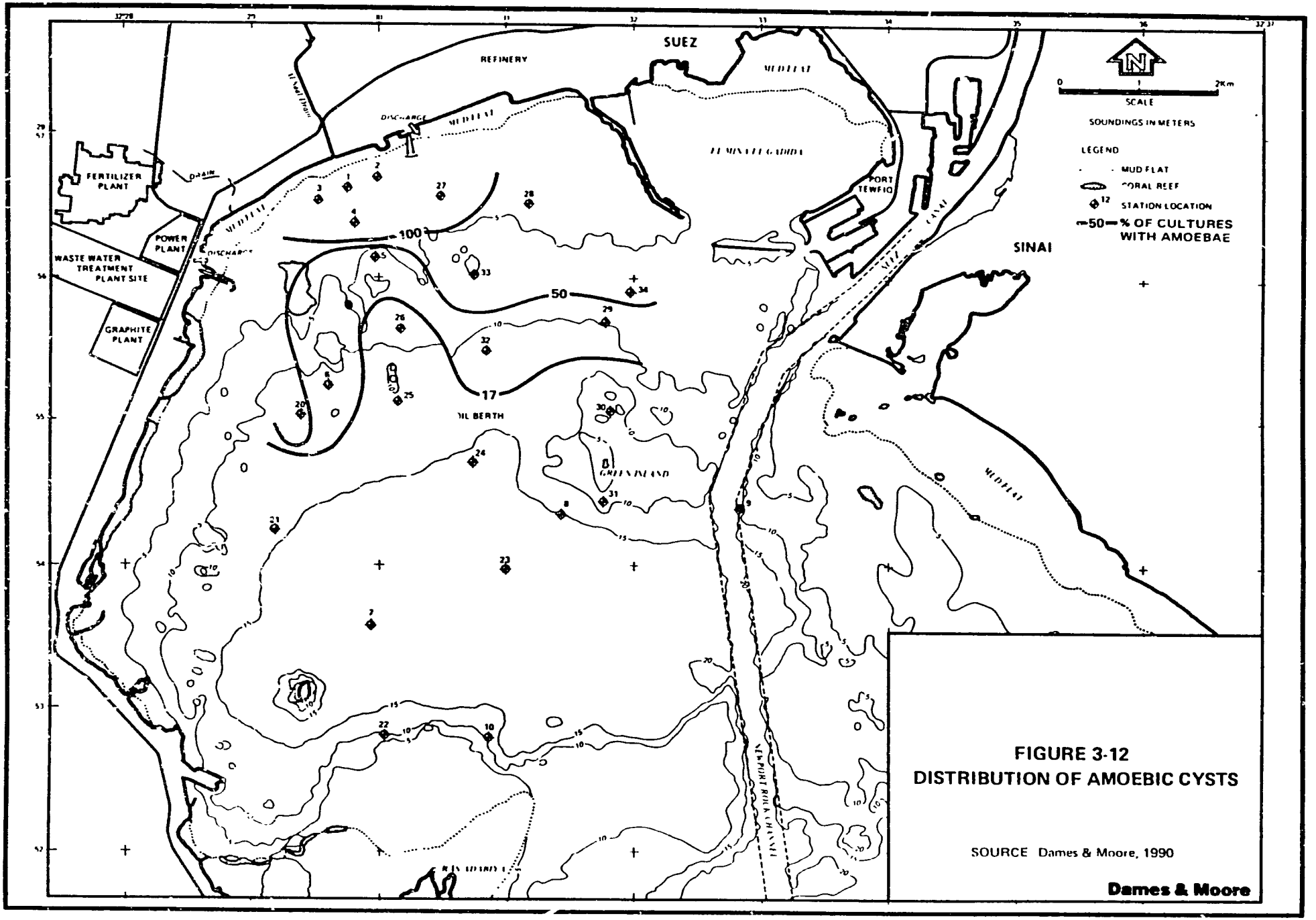


FIGURE 3-12
DISTRIBUTION OF AMOEBIC CYSTS

SOURCE Dames & Moore, 1990

Dames & Moore

northerly and southerly winds, suggestive of nearshore dynamics similar to those seen in Suez Bay, i.e., wind-induced southerly movement of surface waters with replacement by upwelled, northward-moving subsurface waters. Pirnie-Harris International found temperature and salinity values in the Gulf similar to those inside Suez Bay, and reported well-oxygenated seawaters; Gulf waters were well-mixed and vertically homogeneous. Gulf waters were clearer, with Secchi depths ranging from about 5-9 m, two to three times greater than in Suez Bay. Pirnie-Harris International concluded that the Gulf of Suez would be able to assimilate primary effluent without significant adverse environmental effects.

Oil pollution appears to be the most serious environmental problem in the Gulf of Suez, as it is in Suez Bay. Dicks (1987) reports that the Gulf of Suez is one of the largest and most-rapidly developing offshore petroleum production areas in the world, and also one of the most chronically oil-polluted areas. Numerous other researchers have reached similar conclusions (among them Awad et al. 1983; Ferguson 1983; and Mancy 1983).

3.5 Marine Resources

3.5.1 Phytoplankton

During December 1978 and January 1979, a biological survey in Suez Bay revealed a diverse phytoplankton community which included 47 species of diatoms and 19 species of dinoflagellates (Pirnie-Harris International 1979). Dowidar (1976) found 102 species of diatoms and 65 species of dinoflagellates in the same area. However, this earlier study included sampling periods in the summer (July 1969) and winter (February 1970) seasons and used a much finer mesh plankton net. Phytoplankton communities similar to those found in Suez Bay have also been shown to exist in the Suez Canal and in the Mediterranean Sea off the coast of Egypt (Dowidar 1976). The Suez Bay phytoplankton community is characteristic of those associated with oceanic conditions.

3.5.2 Zooplankton

Sampling of the Suez Bay zooplankton community has shown a relatively diverse population. Samples consisted mainly of copepods with the most common being a small cyclopoid copepod, *Oithona* sp. (Pirnie-Harris International 1979). Other copepods found in the samples were determined to be of an oceanic rather than estuarine variety. This is, again, most likely attributable to the high salinity in the bay. Also present in the samples were chaetognaths, appendicularians, doliolids, and a small number of invertebrate larvae. Although common to the samples, they did little to add to the overall biomass (Pirnie-Harris International 1979). In general, species composition in Suez Bay is comparable to those found in temperate to semi-tropical coastal waters around the world (Woodmansee 1958; Grice and Hart 1962; Herman and Beers 1969).

3.5.3 Benthic Fauna

Fishelson (1971) described 79 species of benthic invertebrates found in or on the muddy bottoms of Suez Bay. These include mollusks, sponges, coelenterates, crustaceans, polychaetes, and echinoderms. This work was performed at a time when industries were closed and the Suez Canal was closed to shipping traffic because of war damage incurred in 1967. More recent sampling efforts (Pirnie-Harris International 1979), although not as intense as Fishelson's, have shown significant decreases in the number of species in the bay. This is somewhat surprising, given that the organic nature of the substrate would support a much larger number of species. This phenomenon is most likely attributable to a number of factors including: toxic waste discharge from the industrial facilities along the northwestern portion of the bay; oil spills; the leaching of tributyltins (TBTs) from antifouling paints found on ship hulls; and the continuous dredging operations that occur in the bay.

Awad et al. (1983), as part of a survey of oil pollution in the Gulf of Suez, reported that their station in Suez Bay lacked benthic algae and that only one organism (the bivalve *Modiolus barbatus*) was present. Tissue analysis of that bivalve for total hydrocarbon concentration resulted in a value of 276.4 mg/kg (dry weight). This is comparable to values found in bivalves located near the ballast water treatment plant outfall in Port Valdez, Alaska (Shaw 1988). These data suggest that species sensitive to the presence of petroleum hydrocarbons in the environment may be adversely affected.

3.5.4 Fish

Very little information on the Suez Bay fish resources is available in comparison to other shallow bays within the Gulf of Suez. The majority of commercial fishing effort is concentrated in the northern part of the Gulf but excludes the Suez Bay. The reasons for this lack of fishing effort on Suez Bay include:

- industrial and urban wastewater pollution in Suez Bay;
- oil pollution;
- military activity;
- ship traffic; and
- government discouragement of fishing activity in Suez Bay due to concern over the use of small boats in smuggling operations.

The last major sampling effort took place in the northern gulf in 1964-1965 and was conducted by the Ministry of the U.S.S.R. Fisheries. Table 3-5 summarizes the

Table 3-5. Fish families represented in the samples of the Soviet expedition (1964-1965).

Family Name	Common Name
Clupeidae*	Herrings
Gadidae	Hakes
Mugilidae*	Mullets
Carangidae*	Jacks
Pomatomidae	Bluefish
Moronidae	Sea bass
Syndontidae*	Lizard fish
Scombridae*	Tuna
Soleidae	Sole
Scophthalmidae	Flounders
Triakidae	Sharks

* Commercially harvested (UAR Statistical Data)

fish families represented in the samples collected during the expedition. These species are all believed to occur in or are transient to Suez Bay today; however, they do not appear to occur in Suez Bay in concentrations suitable for commercial exploitation (Pirnie-Harris International 1979).

3.5.5 Marine Turtles and Mammals

Table 3-6 lists the five species of sea turtles that inhabit the Gulf of Suez region. They enjoy fairly abundant (although rapidly diminishing) feeding, egg-laying, and nursery areas along the Gulf's beaches. These turtles are exploited throughout their range for meat, oil, eggs, leather, and shell (Frazier et al. 1987).

No marine turtles are known from Suez Bay. The threatened hawksbill turtle *(Eretmochelys imbricata)* and green turtle *(Chelonia mydas)* both breed further south along the Egyptian Red Sea coast. The northern-most record of marine turtles in the Red Sea is of an immature *E. imbricata* captured at Ras Sudr (29° 36 N) approximately 40 km south of Suez on the Sinai shore (Frazier and Salas 1984).

A limited variety of marine mammals inhabit the Gulf of Suez region (Table 3-6). The dugong, one of a few truly aquatic herbivorous mammals, is known to occur in the region. Seven species of dolphins and two species of whales are known to inhabit the region. Several other whale species (sperm, short-finned pilot, and minke) have been sighted in the southern reaches of the Red Sea but not as far north as the Gulf of Suez. Frazier et al. (1987) postulate that the reasons for this relatively low species diversity include shallow depths, high salinity, and low primary productivity.

3.5.6 Marine and Aquatic Birds

Four main marine and aquatic habitats can be identified at Suez: intertidal mudflats, reed swamps, salt marshes, and open water (marine and fresh water). Each is utilized differently by various birds. Aquatic wetland species are discussed in Section 3.8.

One of the most distinctive wildlife features of the Suez Bay area is the extensive intertidal mudflat which extends from Port Tewfiq in the northeast to Ras Adabia in the south, with an estimated area of up to 1 km^2. In recent years an estimated 2[illegible] of the intertidal flats area has been reclaimed from the sea and filled in with debris and solid waste. The remaining mudflats are heavily polluted with oil, domestic waste, and solid waste. A 1982 study described the levels of oil pollution in Suez Bay as between moderate and extreme (Anon. 1985), with the highest levels of pollution found at El Zytia oil loading port.

The intertidal mudflats are the most attractive habitat for waterbirds in the Suez area and are considered to be the most important on the Egyptian Red Sea and probably in the whole northern part of the Red Sea. Waders use these mudflats more

Table 3-6. Common and scientific names for turtles and marine mammals known to inhabit the Gulf of Suez region.

Common Name	Scientific Name
Hawksbill Turtle	*Eretmochelys imbricata* L.
Green Turtle	*Chelonia mydas* L.
Olive Ridley Turtle	*Lepidochelys olivacea* E.
Loggerhead Turtle	*Caretta carettta* L.
Leathery Turtle	*Dermochelys coriacea* L.
Dugong	*Dugong dugong* Muller
Risso's Dolphin	*Grampus griseus*
Plumbeous Dolphin	*Sousa chinensis*
Spotted Dolphin	*Stenella attenuata*
Red Sea Bottle-nosed Dolphin	*Tursiops Truncatus aduncus*
Gills Bottle-nosed Dolphin	*Tursiops truncatus gilli*
Atlantic Bottle-nosed Dolphin	*Tursiops truncatus truncatus*
Rough-toothed Dolphin	*Steno rostrata*
Killer Whale	*Orcinus orca*
False Killer Whale	*Pseudorca crassidens*

Source: Frazier et al. (1987).

intensively than any other group of waterbirds. While most other waterbirds would use the mudflats largely for resting, waders have their sole source of food there. Table 3-7 presents a summary of two winter, one spring, and one fall counts of waders on the intertidal mudflats of Suez Bay. The table provides an impression of the pattern of use of the mudflats by waders. In addition to migrant and wintering waders, Kentish plovers (*Charadrius alexandrinus)* and spur-winged plovers (*Hoplopterus spinosus)* breed on the intertidal mudflats, but the numbers of breeding pairs are of little significance in comparison to other known breeding areas.

Saltmarsh vegetation is found along parts of the shore of Suez Bay. Zahran (1977) identifies 20 saltmarsh communities along the Red Sea littoral; each of these communities is usually dominated by a single species. At Suez, several communities are found; these are dominated by *Halocnemon strobilaceum, Zygophyllum album, Nitraria retusa,* and *Tamarix mannifera.* A few other non-dominant species are found among these communities. Marginal reed swamp vegetation is found in a few localities along the shores of the bay and scattered among cultivations and urban areas. These are primarily made of *Phragmites australis, Typha* sp., and *Salicornia* sp. Some of these swampy areas are supported by small flows of untreated domestic effluent, e.g., the reed bed just north of the power plant on the bay.

Salt marshes, depending on their plant cover and the availability of water, have varying utility for waterbirds. Species like snipe *(Gallinago gallinago),* wood sandpiper *(Tringa glareola),* and green sandpiper *(Tringa ochropus)* are more likely to be found in the wetter parts of the marshes, while spur-winged plovers (*H. spinosus)* usually breed on the drier edges. Salt marsh vegetation along Suez Bay is used largely by migrating and wintering passerines.

Open water is largely represented by Suez Bay and the Suez Canal. Open fresh water is rare and restricted to canals, although a few brackish ponds are found scattered throughout the area. Suez Bay witnesses a strong movement of gulls (Laridae), terns (Sternidae), and some waterfowl (Anatidae). Although not all the birds passing through the area will actually use the available habitat, undoubtedly some do feed and rest in the bay. Some seabirds, as well as grebes (Podicipedidae) and cormorant (*Phalacrocorax carbo),* also winter in the bay in varying numbers. The presence of oil slicks in Suez Bay is probably a major deterrent to use of this open water habitat by birds.

3.6 Geology and Soils

3.6.1 Site Conditions and Topography

The site of the proposed wastewater treatment plant for Suez is located approximately 8 km to the southwest of the city of Suez, inland of the coastal road from Suez to El Ain El Sokhna. The site generally comprises undeveloped land except for an abandoned pre-cast concrete manufacturing plant in the eastern half and a working gravel quarry in the western half of the site. In addition, a derelict military

Table 3-7. Summary of four wader counts at the intertidal mudflats of Suez Bay.

Species	Season			
	Winter 1979/80[a]	Winter 1989/90[b]	Spring 1982[c]	Fall 1982[d]
Haematopus ostralegus	-	2	49	-
Recurvirostra avocetta	1	-	45	-
Charadrius hiaticula	135	70	200	100
Charadrius alexandrinus	8	312	50	50
Charadrius leschenaultii	55	75	30	20
Pluvialis squatarola	230	180	400	30
Hoplopterus spinosus	32	12	?	30
Calidris minuta	4100	160	1000	1500
Calidris ferruginea	1	-	106	-
Calidris alpina	15	1650	2000	150
Limicola falcinellus	-	-	14	-
Philomachus pugnax	-	-	50	-
Limosa limosa	-	-	1	-
Limosa laponica	-	-	4	-
Numinius phaeopus	-	3	10	9
Numinius arquata	-	19	40	15
Tringa totanus	80	85	100	90
Tringa nebularia	3	3	150	-
Tringa stagnatilis	-	-	10	-
Xenus cinereus	-	-	13	-
Arenaria enterpres	1	14	12	-

a: Meininger and Mullie 1981.
b: Data from a recent IWRB/FORE project (in preparation).
c: Whimpfheimer et al. 1983 (maximum numbers seen on a single day are presented).
d: Baha El Din and Saleh 1983.

bunker system is in the eastern half of the site, and trenches are scattered across the site. The eastern-most part of the site recently has been used extensively for the deposition of waste material. Typically, this material comprises spoil mounds of sand, gravel, and cobbles, and is probably waste material from quarrying or ground excavation works, with some domestic and industrial debris also present.

The surface of the site is generally slightly undulating and slopes gently from the foot of the Ataqa mountains in the west towards Suez Bay to the east. Spoil mounds are typically of 1 m to 2 m height and have been deposited in such a way as to restrict access to the eastern-most part of the site. To the northwest of the site a single spoil embarkment, approximately 10 m high and 100 m by 100 m in plan area, is present. Also present on the site are a number of shallow excavations up to approximately 3 m deep and 25 m by 25 m in plan area.

The surface of the site typically comprises dense sand and gravel. The ground surface is well drained across the site with no standing water observed.

3.6.2 Regional and Site Geology

The proposed site is located on the west coast of Suez Bay at the northwestern extremity of the Gulf of Suez, one of the two northern arms of the Red Sea. The Gulf of Suez and Suez Bay lie on the floor of the western branch of the Red Sea rift, between the uplifted fault blocks of the Gebels of the Eastern Desert in the west and the Sinai Plateau in the east.

The geology of the area is composed of gently folded marine deposits from the Miocene and Pliocene epochs. On the floor of the rift, these deposits are overlain by Quaternary sediments comprising a series of alluvial fans, extending from the base of the raised plateau and recent marine sediments from Suez Bay.

The majority of the surficial soils encountered during the site investigation represent alluvial deposits, and typically comprise gravel with sand, plus some cobbles and silt. The alluvial fan stretches from the base of Gebel Ataqa to the west to the Suez - El Ain El Sokhna Road to the east. This fan has been formed by the erosion and deposition of soil from Gebel Ataqa during infrequent flash floods. These deposits are thought to be underlain by limestone and alternating layers of clay and sand, considered to represent the marine deposits of the Pliocene and Miocene epochs, respectively. More recent marine deposits consisting of carbonate sand, gravel, and coral are found at shallow depth in the eastern-most part of the site.

A total of 9 boreholes to a maximum depth of 10 m were drilled at the proposed site by Geogroup (1982) in March 1981. The boreholes, which were predominantly in the east of the site, indicate a highly layered stratigraphy of calcareous sand and gravel, with occasional silt or silty clay strata. Large quantities of cobbles and limestone fragments were encountered throughout the sand and gravel

layers. The cohesionless deposits were very dense, and the clay was hard in consistency.

A geotechnical investigation of the eastern part of the proposed site was performed from 14 - 18 March 1989 by Dames & Moore. The following is a summary of the stratigraphy found at the site; a detailed description is presented in Dames & Moore (1989).

Two boreholes were drilled at the proposed site, one borehole to 39.5 m and the second to 16.0 m. The surficial soils consisted of carbonate silty sand, gravel, and cobbles, as encountered in previous investigations. These soils were, in turn, underlain from 3.9 m below ground level (bgl) to 6.5 m bgl by a relatively thin layer of moderately weak detrital limestone. Due to the limited depth of the borings, the dip of the limestone and the underlying soil layers cannot be readily assessed. However, from observations from the two borings performed during this investigation, the dip of rock strata can be expected to be in the range of 1 to 2 degrees to the horizontal. An alternating sequence of hard clay and very dense silty carbonate sand was found to underlie the detrital limestone to a depth of 39.5 m.

Soils along the interceptor and force main corridor between the existing and proposed treatment plants consist of alluvial silty sands with some clay and gravel overlying sand, hard clay, and occasional rock. The silty sand comprising the surface soil has a moderate infiltration rate and moderate to low permeability. Groundwater is at or close to the ground surface in the vicinity of the proposed pump station (north of the power plant) and extending northward along the corridor to the El Saal Drain.

3.6.3 Marine Geology

Suez Bay is a shallow depression on the southern margin of the Isthmus of Suez, which separates the Red Sea and Mediterranean Sea (and through which the Suez Canal is cut). Bedrock near Suez Bay consists primarily of Quaternary reef limestones, which attain elevations of 871 m at Gebel Ataqa on the northwestern margin of Suez Bay.

The bay has a natural maximum depth of slightly more than 20 m, but a 23 m deep channel has been dredged to permit deep-draft vessels to gain access to the Suez Canal. The coastal zone is a low-lying coastal plain, narrow on the western side of the bay and broad on the northern and eastern sides. Shorelines along the northern and western sides of the bay are primarily sandy beaches or fringing reefs, and largely sand and mud flats along the southern and eastern sides. Bottom slopes in the bay are generally low (less than 1 to 2°), and extend to the floor of the bay, which is flat and exhibits little local relief.

In addition to the fringing coral reefs, which occur largely along the western shore, there are several small patch reefs scattered about the bay. These are generally

less than 300 m in maximum dimension, except for one larger reef lying immediately off the proposed wastewater treatment plant site.

Sediments comprising the floor of the bay are mainly gray, cohesive, calcareous muds, although some areas of rocky bottom are noted on published hydrographic charts of the bay. Although little has been reported about sediment transport processes in the bay, they are expected to be of low magnitude because of the sheltered enclosed nature of the bay, which serves to reduce wave-induced transport either along the shoreline or in deeper water.

3.7 Groundwater

Groundwater was only encountered at shallow (less than 20 m) depth in the eastern part of the site where the ground elevation is low. Generally, the groundwater level appears to be approximately at the same elevation as the sea level. The groundwater is highly saline, suggesting that it is in hydraulic contact with the sea. Based on the data currently available, the groundwater appears to have little or no hydraulic gradient beneath the eastern part of the site. Further to the west, where the ground level rises, groundwater was not encountered within the first 20 m depth.

The sand and gravel has a relatively moderate to high infiltration rate and permeability depending on the amount of silt and/or clay between the grains. The geological strata beneath the eastern part of the site has a highly variable infiltration rate and permeability, ranging from high in the limestone and sand to very low in the clay.

Ground surface contamination is observed in the eastern part of the site, for example, large pools of crude oil and piles of dumped waste. These suggest groundwater may also exhibit a degree of contamination. At present, the saline groundwater beneath the eastern part of the site could become polluted from ground surface contamination or from lateral flow of polluted groundwater from nearby potential sources, e.g., the adjacent power station or the fertilizer plant further to the north.

Samples of the groundwater were taken at four locations (Stations N/P1, N2, K1, and K3) in the eastern part of the proposed site (Figure 3-13). Visual inspection of one of the samples (Station N2) taken near the power plant indicated the presence of contamination. The groundwater sample consisted of a dark grey liquid with the strong smell of wastewater. Similar observations were made at stations M1 and M4, but the odor was slight to moderate and the color was lighter. Results of laboratory analyses of the groundwater samples are shown in Table 3-8. Bottled mineral water widely available in Egypt was used as a field blank for QA/QC purposes. Groundwater from Station N2, which displayed the strongest odor and color in field surveys, has the highest values in total Kjehldahl nitrogen and phosphorus. These data suggest that the contamination may be due to organic nitrogen and phosphorus, perhaps from activities associated with the fertilizer factory. Depth to groundwater was measured in March

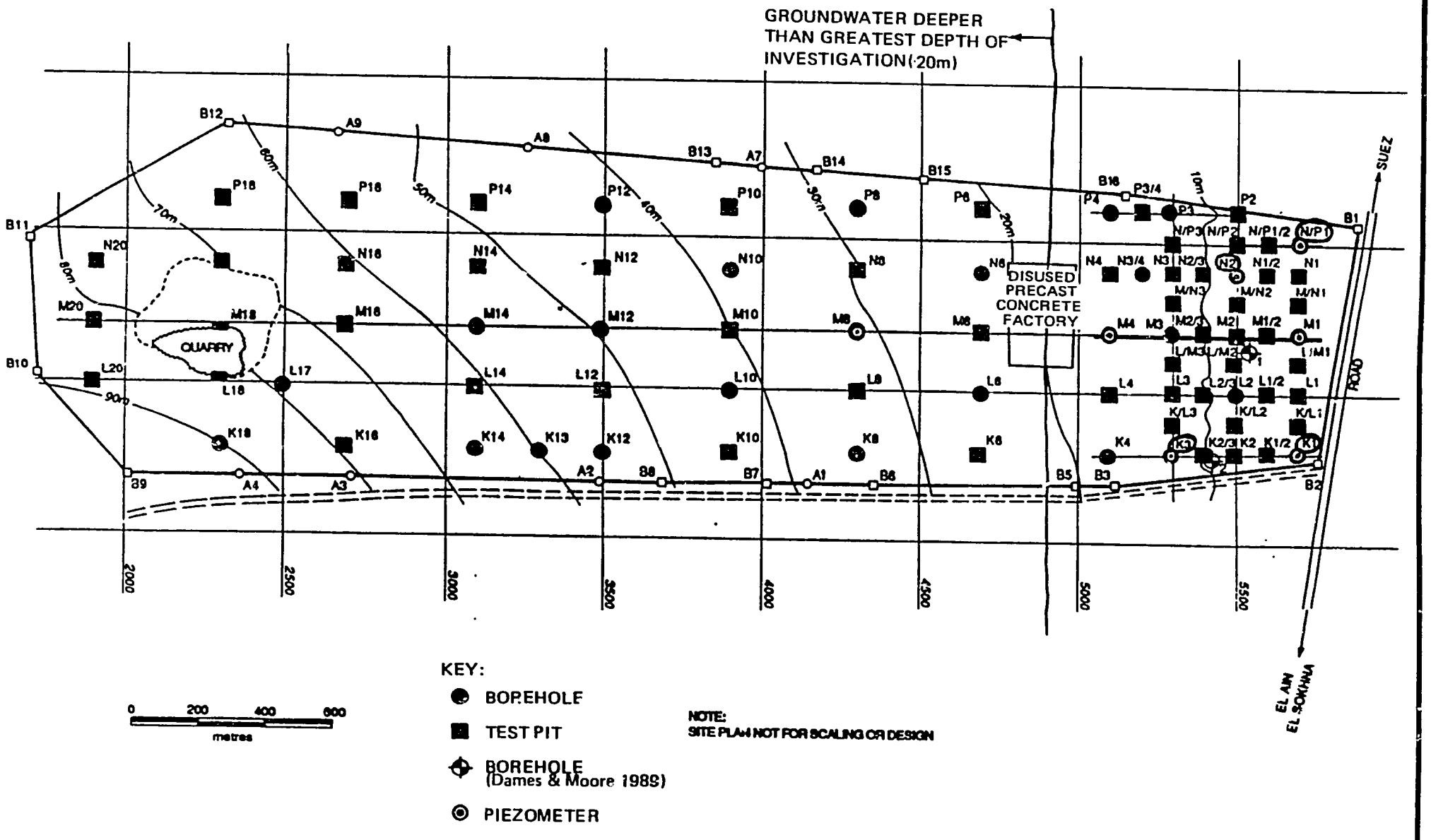


FIGURE 3-13
GROUNDWATER SAMPLING SITES

Dames & Moore

Table 3-8. Results of Groundwater Sample Analysis.

Parameter	Station				
	N/P1	N2	K1	K3	Bottled Mineral Water
pH	7	7	7	7.2	7.8
BOD (mg/l)	50	54	20	20	10
Total solids (mg/l)	32036	21382	24867	20662	539
Total dissolved solids (mg/l)	30810	20850	19550	19900	270
Total suspended solids (mg/l)	1226	532	5317	762	269
Total fixed solids (mg/l)	31946	21288	24832	20624	521
Total volatile solids (mg/l)	90	94	35	38	18
Total Kjeldahl nitrogen (mgN/l)	1.83	11.55	0.77	1.47	0.07
Nitrate (mg/l)	55	50	50	45	45
Nitrite (mg/l)	0.9	0.35	0.6	0.5	0.1
Ammonia (mg/l)	1.2	1.1	0.7	0.6	0.05
Phosphate (mg/l)	0.1	0.4	0.17	0.16	0.2
Conductivity (micromhos)	41000	30000	32000	24000	600
Chlorides (mg/l)	27000	17300	15000	18100	160
Sulphates (mg/l)	3750	3500	4500	1750	60
Salinity (g/kg)	48.8	31.3	27.1	32.7	0.318
Total plate count/lcc	120	8000	36000	900	200
Most probable number of Coliform group/100 cm^3:					
Presumptive Test	Zero	21	46000	93	Zero
Confirmed Test	Zero	Zero	Zero	Zero	Zero

1990 at a shallow depth along the majority of the proposed sewer interceptor and force main route. Generally in the low and poorly drained areas, the groundwater is approximately 1 m below ground level and is saline. Elsewhere, depending on the ground elevation, the groundwater is encountered at between 2 and 10 m depth. Dewatering of the route during construction is probably required along 600 m of the force main trench (south of the proposed pump station) and 2000 m of the gravity sewer line (north of the proposed pump station). Sulphate content of the soil and chloride content of the groundwater indicates significant potential for corrosion of steel. Corrosion resistant pipe will be required. Ground surface contamination is observed at locations along the route, including large pools of crude oil, wastewater in open ditches and depressions, and refuse material.

3.8 Terrestrial and Aquatic Resources

Wadis (dry stream beds that convey water at irregular intervals) are an important ecological feature in the area. They receive soil and water via complexly branched tributaries from an extensive drainage area on the flanks of Gebel Ataqa. Thus, their water supply is many-fold the recorded rainfall in the area, and even a negligible amount of rain might cause flooding. Several wadis dissect the Ataqa plateau draining into Wadi Hagul to the south and Wadi El Bahhara to the north, while on the eastern side several small wadis drain the plateau directly into Suez Bay. The coastal plain east of the plateau strongly slopes towards Suez Bay and is characteristically covered with rough gravel and stones.

3.8.1 Plant Communities

The several small wadis in the vicinity of the proposed wastewater treatment plant site support vegetation typical of this area. The shrub *Hammada elegans* dominates the plant community in areas of gravel and stones while *Zilla spinosa* dominates in areas of deep sand. Other common shrubs are *Anastatica hierochuntica, Atriplex halimus,* and *Lygos shawii.* Higher on the plateau, where water and soil might accumulate, shrubs such as *Zygophyllum decumbens, Fagonia tristis, Limonium pruinosum, Reaumuria hirtella,* and *Stachys aegyptiaca* could be found. Only a few small relict acacia trees (*Acacia raddiana)* are still found here, while dense growths of *Tamarix nilotica* exist along salt marshes bordering Suez Bay (Kassas 1953; Kassas and Zahran 1962).

Several fresh and brackish aquatic habitats are found in the vicinity of Suez; these are largely dependent on the fresh water reaching the area via the Sweetwater Canal, which irrigates agricultural land between Ismailia and Suez and provides Suez with its municipal water supply. The Maghrebi Canal, which runs through the city center, supports several marshy spots amidst the urban area consisting primarily of *Typha* and *Phragmites* swamp patches. These are also found to the north of the city on marginal agricultural land and along canals. A large reed swamp (about 0.2 km^2) that existed just north of the city parallel to the Suez Canal has vanished under a rapidly

expanding shantytown. The most extensive "wetland" area found at Suez until recently was that supported by the existing wastewater treatment plant (1.5 to 2 km^2). The primary flora were *Tamarix nilotica* and *Salicornia* sp., typical of salt marshes in the area. In recent years the plant was upgraded and most of the habitat was destroyed.

Currently the largest aquatic habitat known from the vicinity of Suez is found to the northwest of the center of the city (west of El Ansari district). This is basically the last of what was "the Suez Creek," which was a large shallow lagoon separating the city from the Suez Canal and which received excess drainage water from agriculture land north of Suez. The creek was filled in with silt dredged from the Suez Canal. What is left of the creek is an area of about 1.5 km^2 which is seasonally inundated with shallow brackish water made up of a mixture of saline groundwater, untreated domestic effluent, and agricultural drainage. The creek now supports some growths of *Phragmites, Typha,* and *Juncus* sp. intermixed with mudflats. The area is also used for solid waste disposal.

Much of the natural vegetation in the area has disappeared due to habitat destruction, pollution, and over-grazing. To the north of the city, the Sweetwater Canal carrying Nile water is supporting a small agricultural area and a flora with affinity to the Nile Delta.

3.8.2 Wildlife

Because of the arid conditions prevailing in the region, the natural terrestrial faunal diversity is rather low. With the exception of birds (migratory and wintering birds) the Suez area has no particular significance for wildlife. Many of the terrestrial species typical of the mountainous Eastern Desert potentially may occur in the area, including several rare or declining species. The increasing human presence and the associated habitat destruction and disturbance has caused much of the local native terrestrial fauna to disappear or move further inland where other suitable habitats may exist. The following is a brief review of the characteristic recent terrestrial fauna found in the Suez and Gebel Ataqa vicinity. Additional details are found in Appendix C.

3.8.2.1 Reptiles and Amphibians

The herpetofauna (reptiles and amphibians) represent an important proportion of the known terrestrial fauna of the Suez area. The characteristic herpetofauna is comprised of about 20 species; these are chiefly lizards. Marx (1968) reports 93 species of reptiles and amphibians from Egypt. Thus, there are likely to be a few rare or uncommon species which occur but have not been recorded in the area yet.

Well-vegetated wadi beds draining the Ataqa plateau hold the highest diversity of reptile species. The steep rocky slopes of the plateau provide a suitable habitat for mountain dwelling species, while desert margins alongside salt marshes and agricultural land support species such as Bosc's lizard (*Acanthodactylus baskianus)* and Schokari

sand-snake (*Psammophis schokari*). Agricultural land to the north of the city supports some species typical of the Nile Valley such as the bean skink (*Mabuya quinquetaeniata*); and three species of amphibians are also found in the area. In rocky areas the small-spotted lizard (*Mesalina guttulata*) is the most numerous reptile.

During a field visit on 25 March 1990 to the site of the planned wastewater treatment plant, two species of reptiles were recorded: pale agama (*Agama pallida*) and Bosc's lizard.

3.8.2.2 Mammals

There are about 20 species of terrestrial mammals known from the vicinity of Suez, not including bats. Larger mammals previously known from the area, such as the Nubian ibex (*Capra ibex nubiana*), Dorcas gazelle (*Gazella dorcas*), and striped hyena (*Hyaena hyaena*) have probably disappeared from the locality, certainly from the immediate vicinity of Suez. On the other hand, nocturnal carnivores such as the striped hyena are difficult to detect and could possibly still be found on the Ataqa plateau, where they might descend to the wadis and the coastal plain to feed at night.

The mammal fauna known today from the Suez area consists primarily of rodents and bats. Other than bats, only three carnivores are known to exist in the area: the red fox (*Vulpes vulpes*), Ruppel's sand fox (*Vulpes rueppelli*), and Egyptian mongoose (*Herpestes ichneumon*).

3.8.2.3 Birds

The avifauna is the most prominent and important faunal group represented at Suez. Three distinct groups can be identified: residents, migrants, and wintering birds. There are about 40 resident breeding species at Suez and its environs, while there are more than 250 species of migratory and wintering species. Many of these are uncommon or irregular visitors. Appendix C lists the common birds found at Suez and shows their status and habitat preference.

Reed swamps support many resident waterbirds, such as the purple gallinule (*Porphyrio porphyrio*), moorhen (*Gallinula chloropus*), and painted snipe (*Rostratula benghalensis*). During migration the swamps offer good resting and hiding places for herons (Ardeidae), rails (Rallidae), and waders such as snipe (*Gallinago gallinago*), green sandpiper (*Tringa ochropus*), wood sandpiper (*Tringa glareola*), and spotted redshank (*Tringa erythropus*). Some birds of prey and a wide array of passerines also use the reeds.

Fresh open water is particularly attractive to seabird and waterfowl species. Sewage treatment ponds are often treated by birds as an open freshwater resource, although only insect-eating species such as white-winged tern (*Chlidonias leucopterus*),

black tern (*C. niger*), whiskered tern (*C. hybridus*), little gull (*Larus minutus*), and sometimes black-headed gull (*L. ridibundus*) will use the open water in these ponds to a great extent. Other smaller flying insect-eaters like swallows and martins (Hirundinidae) often feed over the ponds in large numbers, particularly during the migration seasons.

Because of the unique geographic location of Suez, both large soaring birds and waterbirds are concentrated in the area during migration. The larger soaring birds, such as large birds of prey (eagles and vultures) and storks, are dependent in their flight on rising hot air currents (thermals) which are only formed on land. Thus they are land-bound, avoiding all but the smallest water crossing. For birds enroute to and from Eurasia and Africa, Suez is the first land bridge across the Red Sea where several hundred thousand birds of prey and storks pass every spring and fall. On the other hand, waterbirds and seabirds migrate along the Red Sea and the Gulf of Suez, then follow the Suez Canal on their way from and to the Mediterranean Sea. Smaller migrating birds and passerines are also attracted to the many habitats in the vicinity of Suez. The presence of relatively extensive areas of irrigated vegetation and biologically rich man-made habitats around Suez acts as a magnet for many birds after their long flight along the barren Red Sea coast.

The migration of birds of prey and other soaring birds in the area was first reported by Whistler (1916) and Borman (1929). Merchant (1941) and Goodwin (1949) made more detailed accounts of this migration. In recent years and in light of the increasing knowledge about the migration of birds of prey through the Middle East, the phenomenon has been the subject of three extensive studies. The first was during the fall of 1981, producing a total of 133,259 birds of prey of 37 different species passing over Suez (Bijlsma 1983). During the following spring of 1982 a total of 124,996 birds of prey of 28 species were counted (Wimpfheimer et al. 1983). The latest study, carried out in the fall of 1984, produced a total of 92,723 birds of 35 species (Diggelen et al. 1984). Table 3-9 summarizes the results of the three studies.

During the fall studies, an estimated 97% of the birds of prey encountered over Suez belonged to the "very passive" category (defined by Bruun (1989) as birds of prey highly dependent on thermals) which is made largely from short-toed eagles (*Circaetus gallicus*), vultures, and *Aguila* eagles (Diggelen et al. 1984). This makes Suez during fall migration one of the most important concentration points for large ("very passive") birds of prey in the world. In spring the species composition is rather different. During the 1982 study, 66% of the total counted birds were steppe buzzards (*Buteo vulpinus*), which belongs to the "less passive" category birds.

Although most of the migrating birds of prey fly over Suez undetected at high altitudes, many are attracted to freshwater sources and available suitable habitats, and will land to drink and feed if prey is available. This is particularly evident at high ambient temperatures when more birds tend to get dehydrated and exhausted (late April - May during spring migration, and September - early October during fall migration). Considerable numbers have also been noted roosting in the vicinity of Suez, in surrounding desert, and on the Ataqa plateau or in cultivations. The existing

Table 3-9. Summary of birds of prey counts at Suez.

Species	Seasons		
	Fall[a] 1981	Fall[b] 1984	Spring[c] 1982
Neophron percnopterus	437	1002	1193
Gyps fulvus	1284	605	41
Circaetus gallicus	9447	12136	3063
Accipiter nisus + brevipes	64	113	370
Buteo buteo	640	847	80887
Buteo rufinus	1816	217	53
Aquila pomarina	21552	31559	7755
Aquila nipalensis	64380	17498	15775
Aquila clanga	86	42	20
Aquila heliaca	556	178	36
Aquila sp.	31436	27061	8963
Hieraetus pennatus	761	1104	457

a: Bijlsma 1983.
b: Diggelen et al. 1984.
c: Whimpfheimer et al. 1982.

wastewater treatment plant has been noted since 1979 to be a major attraction to birds of prey (Baha el Din, unpubl. data). These were observed drinking raw or partially treated sewage regularly and often hunted for other waterbirds and wildlife attracted to the same location. Large numbers of roosting birds were also noted regularly in the *Tamarix nilotica* bushes which flourished at the treatment plant until recent reconstruction.

Other soaring birds congregating at Suez in significant numbers are: white stork (*Ciconia ciconia*), black stork (*C. nigra*), white pelican (*Pelicanus onocrotalus*), common crane (*Gurus gurus*), and rarely the Dalmatian pelican (*Pelicanus crispus*).

The majority of resident birds are typical of the Nile Valley and Delta, with less than 10 species associated with the desert environment. Cultivated areas north of the city and the city itself support those species with affinity to the Nile Valley. Desert species are found mostly in the well-vegetated wadis west of the city, and some rock-dwelling species are associated with the Ataqa plateau. Appendix C includes resident species known from Suez and its environs.

Four species of resident birds are known from the site of the planned wastewater treatment plant. These either breed on the site or use it regularly for feeding and foraging. The desert lark (*Ammomanes deserti*) and crested lark (*Galerida cristata*) are the most likely to breed on the site, while palm doves (*Streptopelia senegallus*) and collard doves (*S. decaocto*) enter the area occasionally to feed. Mountain dwelling species such as the scrub warbler (*Scotocerca inquieta*), brown-necked raven (*Corvus ruficollis*), and white-crowned black wheatear (*Oenanthe leucopyga*) also visit the site and might breed in the proximity of the Ataqa plateau. Resident waterbirds such as the spur-winged plover (*Hoplopterus spinosus*) and Kentish plover (*Charadrius alexandrinus*) are of special interest because of their potential use of open water at the proposed wastewater treatment facilities.

3.8.3 Endangered Species

Several globally threatened and declining species of birds pass through Suez enroute to their wintering or breeding grounds, and their endangered or threatened status is internationally recognized. Also several locally declining species (including fauna other than birds) might still be found in the vicinity of Suez. These, however, are usually the victims of illegal hunting and critical habitat destruction; thus, most of the locally endangered species have already vanished from the area (e.g., Nubian ibex).

The Convention on the Conservation of Migratory Species of Wild Animals (CMS), or the Bonn convention (to which Egypt is a signatory), lists all migratory species which are endangered or face special problems. The convention lists the species of special concern under two categories. The first are the "Appendix I" species; these are species in gross danger of extinction. The second are "Appendix II" species,

classified as "migratory species which have an unfavorable conservation status and which require international agreements for their conservation and management."

Suez is located on the migration routes of several Appendix I and Appendix II species. Three Appendix I species are regularly recorded from Suez. These are: white pelican, Dalmatian pelican, and the white-eyed gull. White pelican (*Pelecanus onocrotalus)* migrates through the area in fairly large numbers both in spring and fall; a total of 501 birds were counted during the spring of 1982 (Whimpfheimer et al. 1983). Dalmatian pelican *(Pelecanus crispus)* is a rare migrant and winter visitor to Egypt; only 1500 pairs are estimated to still live in the wild (UNEP 1987). At Suez 19 were seen flying over the bay in the spring of 1981 and some may stray there during the winter. The white-eyed gull (*Larus leucophthalmus)* is an endemic seabird to the Red Sea where 30% of the world population (or 1500 - 2000 pairs) breed on Egyptian islands (Jennings et al. 1985). A few white-eyed gulls visit Suez Bay on a regular basis; Whimpfheimer et al. (1983) report as many as 30 in the spring of 1982 at the bay.

The ICBP/IUCN Bird Red Data Book lists several threatened and vulnerable species that are known from Suez (Mountfort 1988). Dalmatian pelican *(P. crispus)* and peregrine falcon *(Falco peregrinus)* are both listed as vulnerable, while marbled teal *(Marmoranetta angustirostris*), corncrake *(Crex crex)*, slender-billed curlew *(Numenius tenuirostris),* sociable plover (*Chettusia gregaria)*, white-eyed gull (*L. leucophthalmus),* and imperial eagle (*Aguila heliaca)* are all considered as candidates for inclusion in the next edition of the Red Data Book.

3.9 Land Use and Services

3.9.1 General

The tip of Suez Bay has been occupied from antiquity since the site is a natural trade node between the northern Nile Valley and the Levant, Arabia, and points east. The central zone of modern Suez City has been inhabited at least since Pharaonic times (Pirnie-Harris International 1979). In recent years, development has spread along the west shore of the Bay south of the city and to the northwest along the Cairo-Suez Road (Figure 2-1). Port Tewfiq was founded in modern times to service the Suez Canal.

Agriculture along the Sweetwater Canal reaches the city's northern edge. To date, urban growth has been slow in that direction. Significant land reclamation is now planned or underway north of Suez on desert soils west of the Sweetwater Canal. Probably cultivated land has not so much constrained urban development northward as have military lands. High groundwater and swamps have slowed development of otherwise desirable areas, such as between Port Tewfiq and the city center and along the harbor's shore. Gebel Ataqa is an obvious physical barrier to growth. It also constrains growth to the southwest because of the risk of flash floods flowing off its slopes.

The Governorate of Suez and the city by that name are not synonymous, although 90 percent of the people in the Governorate dwell in the city. Most of the Governorate's territory is desert. Its area is 1780 km^2, while the four qisms (districts) of the city of Suez cover only 17.1 km^2. The only other population centers are two agricultural towns, El Ganayan and El Shat, north of Suez.

Suez has four distinct areas: Port Tewfiq; Central Suez; the industrial zone along the western shore; and Ataqa/Adabiya, a fishing harbor and port area about 15 km south of the city center. Port Tewfiq, at the tip of the Suez Canal, traditionally has been a self-contained "company town" for Suez Canal Authority employees. Suez Creek and its wetlands separate Central Suez from the port. This area is being drained and reclaimed for housing, so in future years Port Tewfiq and the downtown will grow more contiguous. Oil refineries dominate the industrial zone, but it also contains large fertilizer, textile, quarrying, and power plants. Some scattered housing can be found intermixed with the refineries and factories as companies have constructed apartment compounds for their employees near the workplaces. The proposed wastewater treatment plant (WWTP) site is located toward the southern end of the industrial zone on the west side of Suez Bay, about 8 km southwest of Central Suez and 5 km north of the Ataqa Harbor area.

Approximately 5 km south of the proposed wastewater treatment plant (WWTP) site is the Adabiya port facility, Ataqa Harbor, and a small military base.

The 1986 population of Suez's four districts (qisms) was 280,851 (Table 3-10), out of a total population of 326,820 in the Governorate of Suez. (The districts do not match exactly the city's four areas described above.) The largest district is El Arbeen, the city's traditional core area. Medinat King Faisal, a housing project to the northwest constructed after the 1973 War, comprises the Faisal district. The existing WWTP is located in the industrial zone bordering the Faisal housing project.

Long-range land use planning for Suez is conducted at the Ismailia regional office of the Ministry of Development's General Organization for Physical Planning (GOPP). The GOPP drafts structure and master plans, and these are then reviewed by the Governorate for approval or modification.

The 1976 Master Plan and a new master plan now in preparation by GOPP envision the city growing concentrically outward from the core oriented roughly toward the northwest (Figure 3-14). GOPP also has drafted a plan for development of the Northern Suez Gulf; this plan includes the Port Adabiya area (Figure 3-14) to the south of Suez. Of particular note (Figure 3-14) in these draft plans are:

- Coastal reclamation (clean-up) of areas from Port Tewfiq to opposite the proposed wastewater treatment plant, and south in the Adabiya area.

- Tourism development in the Adabiya area.

Table 3-10. Population of the Governorate of Suez 1976-1986.

District	1976	1982	1986	Growth Rate (percent/yr) 1976-82	1982-86
Suez	29,219	34,074	37,698		
Arbeen	135,575	156,433	172,205		
Faisal	--	40,735	63,170		
Ataqa	3,751	5,599	7,778		
(Urban)	168,545	236,841	280,851	5.83	4.35
El Ganayan	25,420	31,672	45,758		
El Shat	1,171	121	194		
(Non-Urban)	26,591	31,793	45,952	3.02	9.65
Port	--	--	17		
TOTAL	195,136	268,634	326,820	5.47	5.02

Source: CAPMAS 1986

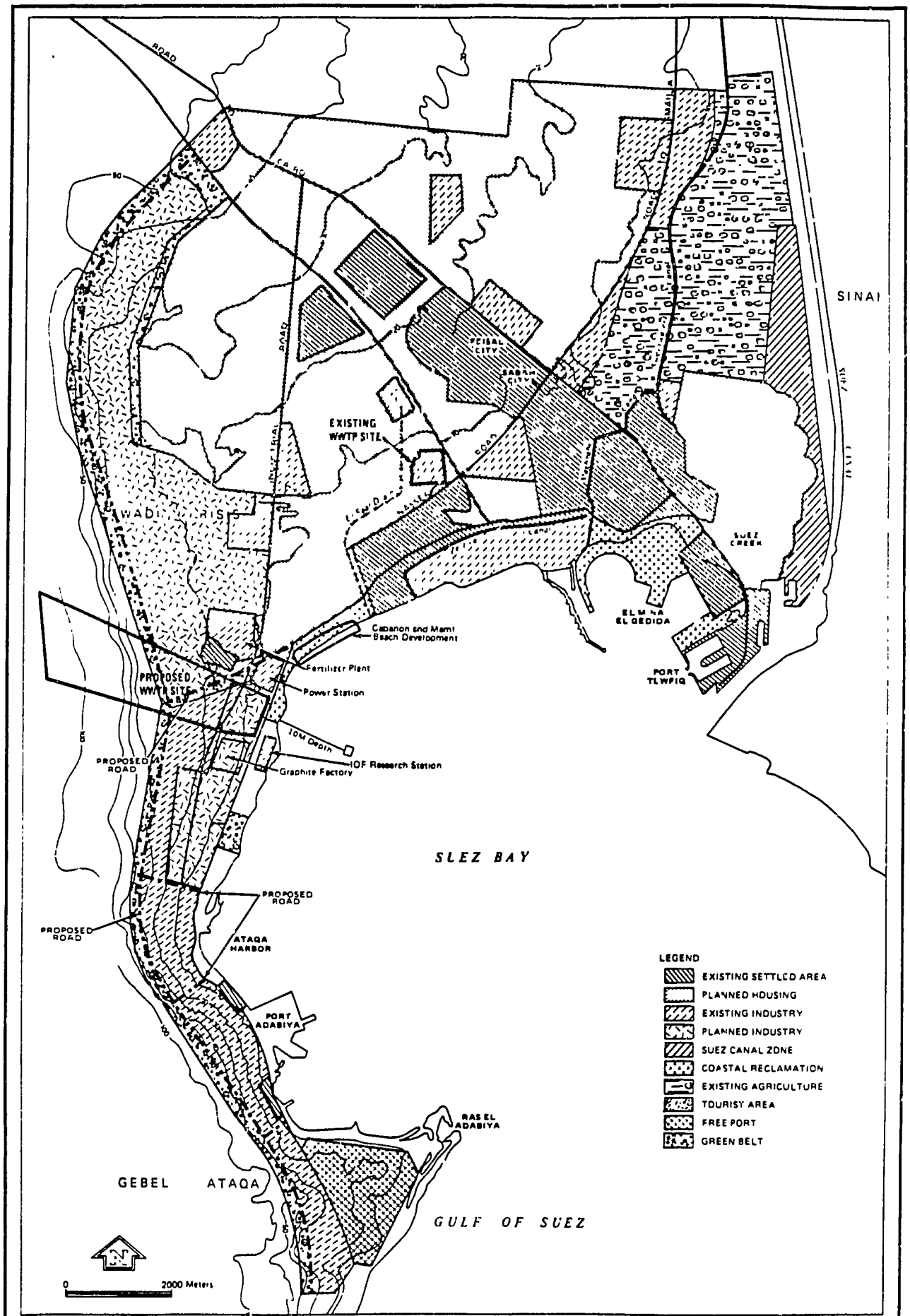


FIGURE 3-14
EXISTING AND PROPOSED LAND USE

Dames & Moore

- A north-south bypass road along the base of Gebel Ataqa that would cross the western end back of the proposed treatment plant site, and a cross-over road passing through the site from the proposed bypass road to the existing coastal road. The present coastal road would become a secondary route for local traffic.

- A greenbelt along this north-south road.

- The area immediately west and north of the existing treatment plant is designated for housing and a park, respectively.

These draft plan proposals, however, have not yet been adopted by the Governorate.

Coastal reclamation generally consists of removing debris from along the shoreline and improving aesthetics. Removing debris and developing the shoreline is important in the city's development plans. In the 1980s, the city worked to reclaim and make into a park the shore along the inner harbor, which had been debris-filled mud flats following the 1973 War. Tourist cabins were built on the shore at Port Tewfiq. A swimming beach was developed in the inner harbor, although water quality conditions are not known.

Further down the coast, national tourism development plans call for developing scattered sites along the Gulf of Suez and Red Sea coast.

3.9.2 Existing and Proposed Wastewater Treatment Plant Sites

The existing wastewater treatment plant (WWTP) is located west of the city center and just north of the beginning of the industrial area. As mentioned above, longer term plans call for filling in this general area with housing. New apartment housing is under construction about 1 km to the northeast of the existing WWTP. A park is under construction approximately 1 km north of the existing WWTP. These new developments will be upwind of the existing WWTP for the majority of the time, and are sufficiently removed to avoid nuisance odor and insect problems. During infrequent winds from the south, residents living in the nearby new housing or using the park may be exposed to odors from the WWTP. These odors, however, are likely to be masked by emissions from the oil refineries located south of the existing WWTP.

The existing WWTP currently discharges minimally treated waste into the El Saal Drain, which flows 4-5 km to the Bay. This drain borders several areas of formal and informal housing. An estimated 200-400 people live near the El Saal Drain outlet to Suez Bay. The El Saal Drain south of Suez's treatment plant contains mainly untreated sewage. This represents a significant nuisance and public health hazard to nearby residents.

The site for the proposed wastewater treatment plant lies in the industrial zone along the coastal road between the power station and fertilizer plant to the north, and a site designated for a graphite factory to the south (Figure 2-1). A 960-feddan site has been reserved for the plant, its future expansion, and for sludge disposal. It is a rectangular area oriented east-west, sloping gradually upward to the base of Gebel Ataqa. The initial facilities will occupy about 125 feddans on the eastern end of the site.

In addition to an abandoned pre cast concrete manufacturing facility in the eastern half, an active gravel quarry in the western half, and abandoned military fortifications, the site is traversed by overhead high voltage power lines and by underground oil and gas pipelines. A dirt road along the southern edge of the site leads to the quarries and beyond to an abandoned mountainside guest house and foot trails leading up the mountain.

There are two housing areas located near the proposed WWTP site. One is located at the recently re-built Institute for Oceanography and Fisheries (IOF) research station. Currently 10 families of staff members live on the site south of the IOF main building, approximately 200-500 m southeast of the proposed WWTP site. Housing for an additional 20 families has been or is being constructed on the site for future staffing increases at the research station.

The second housing area located near the proposed WWTP site is a set of apartment buildings housing about 4000 employees of the fertilizer plant. The housing is located west of the fertilizer plant, at least 1000 m from the proposed treatment lagoons, but within 500 m of the sludge lagoon area.

Approximately 3,000-5,000 people live in the military base and a small settlement around the Ataqa Harbor/Port Adabiya area, located about 5 km south of the proposed treatment plant site. Economic activity in this area includes a fishing harbor (in the Gulf of Suez) and grain shipment facilities. Plans have been prepared to develop a manufacturing-oriented free zone, but no time schedule appears to be in place for such an expansion.

3.9.3 Suez Offsite Facilities

The proposed new offsite facilities at Suez consist of a 4.1-km long sewer trunk line from the existing wastewater treatment plant to a proposed new pump station, and a 1.4-km force main from the proposed pump station to the proposed wastewater treatment plant site further to the southwest (Figure 2-3).

Starting from the existing WWTP the sewer line runs adjacent to the open El Saal Drain channel which is in the west of housing and a petroleum refinery (Figure 2-3). A large storage area for pipes is present to the east of the proposed sewer line, approximately 0.5 km from the existing WWTP. The proposed sewer line passes through an area of informal housing and over an old wastewater drainage channel.

Beyond this the line continues to the southwest, whereas the El Saal Drain flows to the southeast and eventually into Suez Bay. Up to this location the ground is gently undulating to flat and predominantly well drained. Further to the southwest the sewer line traverses areas which are flat, low lying, and poorly drained until the proposed pump station is reached. This area is occupied by informal housing, and sparse vegetation is used by grazing goats and sheep.

The proposed new pump station is situated in a flat area of low-lying, poorly drained land adjacent to informal housing. To the west of this location is the fertilizer plant.

The proposed force main alignment continues to the southwest of the pump station, then runs parallel to the road to the fertilizer plant. It then turns south (to the west of the Ataqa Power Station) before reaching the proposed wastewater plant. The land along the force main route slopes to the east and is generally well drained.

The offsite routes generally traverse undeveloped land, except in the vicinity of the informal housing and adjacent to the fertilizer plant and power station. In addition the route is crossed by several surface and underground facilities including roads, a railway line, pipes, and cables.

The ground surface generally consists of sand which varies from being well drained to being low-lying and poorly drained.

3.9.4 Demography

After the 1973 War, the Egyptian Government reopened the Suez Canal, rebuilt the three Suez Canal cities, and made plans to develop the region as a countermagnet to draw growth away from Cairo, Alexandria, and the Delta region. Various studies cited Suez as the region's most promising growth point. The 1976 Suez Canal Regional Plan set a year-2000 target population of 990,000 for the city, although its 1976 population was only 168,545.

The city has not grown as rapidly as the 1976 Master Plan called for or was forecast by many studies completed since, including the 1979 Suez Wastewater Master Plan (Pirnie-Harris International 1979) and the USAID Canal Cities Phase II Project Paper (USAID 1987). For example, the 1976 Master Plan foresaw a 1990 population of 692,000, while in actuality it is now about 333,000 (Table 3-10). The city's growth depends mainly on creating new jobs in industry, foreign trade, and Suez Canal services. Other urban areas such as Cairo, Alexandria, and new towns (such as Sadat City, New Ameniya, 10th of October, and 5th of Ramadan) have proven more attractive to new industry. Foreign trade and Suez Canal shipping suffered from the Middle East region's 1980s economic slump following the sharp decline in oil prices in 1983.

Forecasting growth of Suez and the Canal Cities is complicated by their resettlement after the 1973 War, which distorted growth rates upward in the 1970s. The draft of the new Suez Master Plan has made "high" and "low" forecasts of Suez City's population growth to 2015, using the 1982-1986 growth rate as a starting point (Table 3-11). The high and low forecasts make differing assumptions about base growth and net migration. They estimate the year-2005 population will lie between 561,788 and 630,949. The proposed WWTP is expected to serve 86% of the lower population projection of 561,800 in 2005 (CMC 1989).

3.9.5 Water Use and Wastewater Flow

The available data allow preparation of an approximate potable water balance for Suez. The potable water plant supplies roughly 100,000 m^3/day (Table 3-12), while the wastewater treatment plant receives 67,000 m^3/day (CMC 1989). About 35,000-40,000 m^3/day of supplied water does not reach the collection system. Some is lost before reaching the user; users "consume" a small amount; and the rest fails to reach the collection system after use due to evaporation, runoff, leaching into the ground, or discharge to points other than the collection system.

The wastewater has a total dissolved solids (TDS) content of 5,300 ppm and 1,200 ppm chloride (Cl), compared to the potable water's TDS of 700 and 200 ppm Cl. Since groundwater Cl is 10,000-20,000 ppm (CMC 1989), calculations show that infiltration must be 5-10 percent.

Water use data are not kept by the standard categories of residential, commercial, and industrial. Table 3-13 shows 1988-89 water use by the municipality's classification of user type. "Losses and Treatment Plant Use" likely represents the discrepancy between potable water produced and that known to reach users. Some fraction of this must be losses in the delivery system. The largest users are "Government" and "Residential." Table 3-14 disaggregates "Government" use, revealing it to be a mix of residential, office, and industrial uses. Table 3-15 breaks down "Residential" use by district. This flow likely includes some commercial and small-scale industrial users.

Available data suggest that Suez's refineries, factories, and other industries are not large water users. Table 3-16 lists most of the city's largest operations and their water use, which totals only 6,392 m^3/day. Water use by "Oil Companies" in Table 3-14 is only 2,781 m^3/day. This at least approximates the use by oil-related companies listed in Table 3-16, which totals 3,544 m^3/day. The major industrial users do not discharge wastewater into the municipal wastewater collection system (Zeld, pers. comm.).

According to the 1979 Suez Wastewater Facilities Master Plan (Pirnie-Harris International 1979), gross water use by the newer residential areas is 217 liters/capita/day (lcd), with the actual use (less wastage) being 137 lcd. For mixed residential-commercial-industrial usage, Pirnie-Harris International (1979) estimated 263

Table 3-11. Suez City "High" and "Low" Population Projections for 1986-2015.

Period	Population Growth %		Population at end of Period	
	Max.	Min.	Max.	Min.
1982-1986	4.35	4.35	280,851	280,851
1987-1990	4.35	4.35	333,027	333,027
1991-1995	4.35	4.22	412,083	409,413
1996-2000	4.35	3.26	509,905	480,643
2001-2005	4.35	3.17	630,949	561,788
2006-2010	4.35	3.08	780,726	653,750
2011-2015	4.35	3.00	966,058	757,728

Source: CMC (1989) and GOPP Office of Regional Planning, Ismailia.

Table 3-12. Monthly Water Supply from Suez Potable Water Treatment Plant July 1988 - June 1989.

Month	Production (m^3)
July 1988	3,297,360
August	3,405,200
September	3,218,790
October	3,195,680
November	2,783,790
December	2,726,410
January 1989	2,671,050
February	2,273,620
March	2,724,450
April	2,932,940
May	3,364,225
June	3,639,310
Average (m^3/day)	99,268

Source: CMC 1989.

Table 3-13. Suez City: Water Use by User Type 1988-1989.

User	Quantity (m^3/day)	Discharge Point
Government	26,352	WWTP
Residential	27,629	WWTP
"Free" Water Points	359	WWTP
Suez Canal Authority Offices	4,855	WWTP
Suez Canal Authority Housing	1,119	Suez Canal
Unmetered Connections	17,261	WWTP
Losses & Treatment Plant Use	21,694	WWTP
TOTAL	99,269	

Source: CMC 1989

Table 3-14. Suez City: Water Use by the Government and Public Sector 1988-1989.

User	Number of Meters	Total Use (m^3/day)
HEG Pt. Tewfiq	4	8
Oil Companies	16	2,781
Mosques	100	102
Schools	4	12
Power Company	10	39
Public Housing	71	4,099
Clubs & Societies	26	141
Syndicates	5	19
Government Offices	466	8,619
Railway	11	570
Army	20	652
Public Sector	314	6,863
Utilities	1	17
Home Societies	15	129
El Oboor City	248	558
El Sadat City	200	1,005
Fast Homing City	56	82
El Sabah City	216	336
El Garib	156	304
TOTAL	1,939	26,336

Source: CMC 1989
Note: Total use differs from "Government" in Table 3-13 due to rounding.

Table 3-15. Suez City: Water Use by District 1988-1989.

User	Number of Meters	Total Use (m^3/day)
Zarb & Farz	535	1,111
El Mohafaza El Gedid	293	608
El Salmania	420	872
El Ghareib	537	1,115
El Mohafaza El Qadim	405	841
El Morour	375	779
Tel El Qalzem	1,006	2,089
Geledan El Sharky	520	1,080
Kafer Kamel	1,396	2,899
Okda Kafer	1,140	2,367
Kafer Hoda	1,150	2,388
Abu Eleiz Kafer	1,040	2,160
Kafer Hoda New	630	1,308
Kafer El Nagar	1,230	2,554
Selim & El Arab	1,102	2,289
El Zayteia	310	644
El Ganayen	590	1,225
New Ahmed Abdou	365	758
Port Tewfiq	260	540
TOTAL	13,304	27,627

Source: CMC 1989
Note: Total use differs from "Residential" in Table 3-13 due to rounding.

Table 3-16. Suez City Water Use by Selected Industries 1987-88.

Company	Water Use (m^3/day)
Skony Fakson Petroleum	34
Al Taawnia Petroleum	6
Petroleum Pipes Co.	822
Petroleum Gas Co.	91
Oil Mixing Factory	6
Petroget Co. (petroleum)	125
Egypt Oil Co.	12
Misr-Gulf for Oil	209
Kaltex for Petroleum	7
El Nasr Oil Co.	397
Suez Oil Refining	315
El Nasr Co. for Well Oil	260
Eastern Co. for Petroleum	274
Petroleum-related Subtotal	3,544
Meratex (textile)	986
Ships Workshops	117
Ports Refreezing Co.	71
General Co. for Refreezing	30
Arab Co. for Petroleum Pipe	279
Nile Co. for Transportation	85
Egyptian Co. for Navigation Supply	767
Arab Co. for Medical Glass	493
Ataqa Cement Factory	986
TOTAL	6,392

Source: CMC 1989

Note: Effluent from these facilities is reported to be not discharged to the treatment plant.

lcd gross and 166 lcd net. In 1989, roughly 300 lcd was being produced at the water supply plant, and 246 lcd reached the treatment plant from the estimated 82 percent of the population connected. Thus, current gross water use must be at least 250 lcd.

Suez's water use is high compared to the national average and typical planning standards. In the early 1980s, Egypt's urban areas averaged 167 lcd for all uses, with 100 lcd reaching the wastewater collection systems (Dames & Moore 1985). The 1985 Land Master Plan for Irrigation Development (Euroconsult-Pacer Consultants 1985) used the values shown below as planning standards for new urban areas with over 10,000 population:

Domestic	120 lcd
Commercial	15 lcd
Industrial	20 lcd
Public Sector	10 lcd
Losses	15 lcd

Total	180 lcd

Suez's water use is high, 250 lcd or more, because of losses in the distribution system and wastage (uncontrolled flows after the water reaches users). Per capita flow to the wastewater collection system is high, over 240 lcd, because of this inefficient water supply and use, not because of infiltration or high use by industry. Industry uses little water (Table 3-16) and does not discharge to the collection system.

Besides inefficient supply and use, Suez also has quality problems with its potable water. When the Sweetwater Canal terminates at Suez, it has received the drainage from agricultural land along more than 100 km of its banks. Suez's potable water TDS averages 700 ppm, compared to the recommended 500 ppm maximum. Quality will only get worse in future years with increasing demands on a limited supply of Nile River water.

3.10 Energy

Electricity generation in Egypt is primarily by fossil fuels (oil and natural gas) and hydropower (Aswan Dam), with hydropower comprising 24% in 1988. A relatively new, oil-fired power plant is located on the shore of Suez Bay just north of the proposed wastewater treatment plant.

Like many developing countries, Egypt heavily subsidizes energy. Explicit and implicit energy subsidies during fiscal year 1989-90 will amount to about 10 percent of GDP, i.e., LE 4.7 billion for petroleum products and LE 6.3 billion for electricity. This represents the largest subsidy of any category (Adler 1990). Energy subsidies have been a focal point for the World Bank/IMF and USAID in their policy reform dialogues with Egypt.

Energy subsidies encourage energy waste; energy-intensive technologies are favored, and projects are implemented that would be infeasible had energy inputs been fully priced. High subsidies helped spur commercial energy use growth of 11 percent/year during 1974-85. This helped make Egypt an "energy intensive" developing country, consuming about 64 percent/year more energy than the average for countries at its level of development.

Since 1985, the Egyptian government has been increasing commercial and residential electricity prices, but they remain well below developed-country levels. Over the past 2-3 years, US residential consumers have paid about 7.5 cents/kwh and commercial users about 6-6.5 cents/kwh, while Egyptian users have paid less than 2 cents/kwh (Adler 1990). USAID studies have found that Egypt's average tariff for electricity in recent years (approximately 3.6 piasters/kwh, or 1.5 cents/kwh) has been about 20 percent of the long range marginal cost (LRMC) of generation from new plants.

To account for real resource scarcities, USAID requires project feasibility analysis using "economic" or shadow prices of labor, capital, energy, and other inputs. Regarding energy, the shadow price for petroleum is basically its world market price, and for electricity, the LRMC of generation from new plants.

USAID studies find that the LRMC of electricity in Egypt over the past 2-3 years has been about 19.8 piasters/kwh. Using USAID's 1989-90 estimated shadow foreign exchange rate of 3.00 LE/US dollar (about 15 percent higher than the most widely used rate), the LRMC in dollars equals 6.6 cents/kwh. This is similar to actual costs and prices in the US. The World Bank calculates an LRMC of approximately 10.4 piasters/kwh in 1989 prices. In either case, this is significantly more than the present cost for energy in Egypt.

For the fiscal year 1988/89, about LE 300,000 was allocated by the Suez Wastewater Department to energy costs. This amount, representing 18% of the budget, was designated primarily for electricity to operate the collection system pumps.

3.11 Air Quality

Air quality monitoring data have not been collected in Suez. It is likely, however, that emissions from the oil refineries and from numerous ships anchored in the area to await their turn to transit the Suez Canal cause localized deterioration of air quality. Winds are predominantly from the north-northwest quadrant year-round (Figure 3-2), with a secondary importance of winds from the south-southeast quadrant during December-April. Thus, most of the emissions from the oil refineries and shipping traffic are blown offshore and perhaps rapidly dispersed.

3.12 Archaeological Sites

As mentioned in Section 3.9.1, the core area of Suez City has been occupied since antiquity (Pirnie-Harris International 1979). Canals and roads stretched north along the present Sweetwater Canal and northwest to the city's water source at Bir Soueyz 5 km distant, and on to Cairo. The entire area of Central Suez is underlain by ruins, and more are likely to be scattered along the north and northwest axes.

Archaeological ruins have not been reported on the proposed wastewater treatment site. The locale is some distance from the ancient town and, being on an outwash plain at the foot of Gebel Ataqa, not particularly suited for habitation. It is unlikely that settlements occurred on the proposed site. Trails and tracks along the coast probably have passed through the site for centuries. Thus, there is a small chance of encountering artifacts or other small archaeological finds associated with such activities.

CHAPTER 4

4.0 ENVIRONMENTAL EFFECTS OF THE PREFERRED ALTERNATIVES

The preferred alternatives include construction of a wastewater treatment plant with aerated lagoon treatment at a site located on the west shore of Suez Bay. Effluent will be discharged to Suez Bay with an outfall at a minimum depth of 10 m, and sludge will be disposed of in a quarry located at the west edge of the treatment plant site.

4.1 Climate and Meteorology

It has been recognized in recent years that man's activities might cause changes in weather and climate. Short-term variations of meteorological parameters would entail "weather changes", while their long-term variation would be termed "climate changes." Climatic changes can occur on a local scale (micro-climate) as well as a global scale. None of the activities associated with the construction or operation of a new wastewater treatment plant, or discharge of treated wastewaters to Suez Bay, are of a magnitude large enough to adversely impact local weather and climate. Although the preferred alternative will require the greatest amount of energy (Section 4.10) to operate the facilities, the annual consumption in equivalent barrels of oil per year is 14,000 bbl. The emissions from this amount of power generation are insignificant with respect to global warming as a result of fossil fuel burning.

4.2 Physical Oceanography

Identified in this section are possible impacts that the discharge of treated wastewater may have on the physical character or behavior of Suez Bay seawater. Two general sources of potential impact are recognized: a) construction and physical placement of the outfall structure, and b) discharge of treated wastewater to the bay.

Structures placed in the marine environment may modify water flow, create turbulence, and affect local sediment transport. If the submarine outfall alternative is selected, the installation of the outfall will temporarily create disturbance of the seafloor and will cause some short-term re-suspension of bottom sediments. Water column turbidity will increase during construction and will reduce light penetration, and thereby may temporarily affect phytoplankton growth in the construction area. These adverse effects are expected to be short-lived and localized, and are not considered to be significant because ecological productivity and diversity in Suez Bay does not appear to be high.

The outfall structure will induce some local turbulent mixing by ambient currents. This is not considered a negative impact, and will aid in the dispersion of the wastewater effluent.

Discharged wastewaters will have significantly different physical characteristics than Suez Bay receiving waters. The effluent will be fresher and (at some times of the year) warmer than receiving waters. As a result of its lower density, the effluent will rise towards the surface as it mixes with Suez Bay waters. Preliminary dispersion modeling of the discharge plume from the preferred 10-m deep outfall in the presence of typical ambient flows indicate that dilution of approximately 100:1 will occur within 10 meters of the discharge site. Impacts to the physical oceanographic environment are expected to be highly localized and insignificant.

4.3 Water Quality

4.3.1 Construction Impacts

Marine water quality may be impacted during outfall construction by the re-suspension of marine sediments, which will increase turbidity and decrease light penetration. These effects will be short-lived (on the order of a few weeks of construction) and highly localized (probably within a hundred meters of the site). Impacts on water quality will be adverse but not significant.

4.3.2 Operational Impacts

The major environmental effects of sewage discharges into marine waters derive from the following factors:

- Increased oxygen demand and consumption through biological or chemical oxidation of decomposable organic matter.
- Increased nutrient loading (primarily nitrogen and phosphorus) and secondary biostimulatory growth of phytoplankton.
- Human health problems associated with enteric pathogens such as bacteria, viruses, protozoans, and other parasites.
- Acute or chronic toxic effects from trace metals, chlorinated hydrocarbons, cyanide, phenols, and other chemicals that may be discharged to the sewer system by industry in the future.
- Aesthetic degradation from suspended and settleable solids, oil and grease, and floatable materials.

The severity of the impacts from the proposed discharge will be a function of the relative contaminant concentrations in the discharge, background levels in the receiving waters, rates of mixing and dispersion, and possible cumulative effects with pollutants from other sources. Many of these factors are not known at this time and limit the assessment of environmental impacts to more general considerations. The concentration of pollutants in the receiving water will depend on the dispersion of the wastewater plume and the performance of the treatment plant.

It is clear, however, that the proposed discharge will be a significant improvement over current practices, and therefore the overall benefit is expected to be an improvement in water quality.

4.3.2.1 Wastewater Plume Dispersion

Dispersion of the plume is a function of the discharge rate, concentrations and physical characteristics of the waste materials, and the magnitude of local currents, current shear, vertical density stratification, and wind-induced mixing. These were investigated using a numerical dispersion model (Dames & Moore 1990). The model was run, in the absence of specific design parameters for the proposed submarine discharge, with effluent conditions similar to the existing wastewater stream, and outfall design parameters typical of ocean outfalls (Appendix B).

The results of the numerical modeling indicate that by the time the effluent plume reaches the water's surface, it will have achieved a dilution of between 24:1 and 101:1 for a 5-m deep outfall, and between 64:1 and 195:1 for a 10-m deep outfall (Appendix B). The lower values in both cases are for zero current conditions (the worst-case condition), while the higher dilution values are for current flow conditions that are commonly found at the discharge site. After this initial rapid dilution stage (the zone of initial dilution), the wastewater plume is further diluted as it is transported away from the discharge site.

Although no long-term current measurements have been made at the proposed discharge site, 12 profiles taken during the Winter 1989 survey (Appendix B) indicated that surface flows are predominantly southerly, while flow between 5 and 10 m depth is predominantly northward. The surface flows are believed to be caused by the dominant winds, which blow from northwest to southeast, and the subsurface countercurrent represents waters drawn shoreward and to the surface to replace surface waters advected offshore. Reversals of that pattern may occur during times of strong and/or persistent southerly winds. Onshore winds (blowing from the southeastern quadrant) occur 13% of the time on an annual average basis; the month of March has the highest occurrence (23%) of such winds.

Thus, plume dispersion analyses indicate that discharge to deeper water (at least 10 m deep) would be environmentally preferred because of the greater dispersion and dilution expected in deeper water. Furthermore, a discharge located farther from shore will produce a larger degree of dispersion from far-field mixing processes (those occurring outside the zone of initial dilution). Finally, the climatic and current data indicate that the surfaced plume will be driven southward toward the Gulf of Suez the majority of the time.

4.3.2.2 Microbiological Contamination of Recreational Beaches

A recreational beach club (Green Beach) exists along the new power plant shoreline near the proposed outfall site. Although Green Beach was apparently closed during field studies and site visits in 1989-1990 and facilities were in poor repair, private investors are reported to have plans to restore it. Thus, Green Beach is a potential water contact area. The beach in front of the Institute of Oceanography and Fisheries research station (IOF) is also a potential water contact area, although not likely to be for public use. Green Beach and the IOF lie approximately 900 m from the 5-m outfall site and 1400 m from the 10-m site. Estimates were made of the fecal coliform concentration that might be experienced at Green Beach under the (apparently unusual) condition of an onshore surface flow of the wastewater plume.

If it is assumed that: a) fecal coliform concentrations in the raw wastewaters are 1×10^7 organisms/100 ml, b) 96% of the fecal coliforms die in the treatment plant, c) the wastewaters are not chlorinated, and d) surficial receiving waters are moving onshore at a speed of 0.20 m/sec, then the following analysis pertains:

- The end-of-pipe fecal coliform concentration (immediately prior to discharge) is 400,000 organisms/100 ml.

- Using a nominal 50:1 dilution ratio for the 5-m outfall and a 100:1 dilution ratio for the 10-m outfall, the concentration of organisms at the water's surface is then 8000 and 4000 organisms/100 ml for the two outfalls, respectively.

- It will require 75 minutes for the discharge plume to reach shore from the 5-m discharge site and 116 minutes from the 10-m site.

- Assuming a coliform die-off rate (T^{90}) of 120 minutes (an approximate average of widely varying reported values), coliform concentrations at the beach would then be expected to be approximately 3500 organisms/100 ml for the 5-m outfall and 520 organisms/100 ml for the 10-m outfall.

For a number of reasons, these computations must be considered as first approximations only. Inadequate current data exist at the proposed discharge sites to

provide good estimates of the frequency and magnitude of onshore flow. The initial dilution values shown are sensitive to outfall design and may differ from the assumed values used above. The dilution rates for typical currents measured in December 1989 produce dilution rates two-fold higher than those used in this analysis. This last point in particular offers a degree of conservative analysis to the computations.

Reported coliform die-off rates vary over an order of magnitude and are dependent on numerous site-specific parameters; the rate might be expected to be high in Suez Bay because of the very warm, unusually saline waters, and the high solar insolation rates (sunlight is known to be bactericidal). On the other hand, a growing body of literature indicates that fecal coliform die-off rates in marine waters have been significantly over-estimated. Data collected in Alexandria, Egypt during a field study of disappearance rates of total and fecal coliforms and fecal streptococci showed that the rate was significantly influenced by time of day (French, pers. comm.). For the analysis of wastewater discharge off Alexandria, a daytime T^{90} value of 1.5 hours was adopted for fecal coliform counts. A T^{90} value of 40 hrs was adopted for nighttime conditions.

The data indicate that discharge via an outfall in 10-m deep water would offer greater protection to potential recreational use of Suez Bay. Initial dilution using the parameters noted above shows that fecal coliform counts meet the Law 48 criterion (5000 MPN/100 ml) within the zone of initial dilution by a larger margin for the 10-m outfall. Law 48, however, does not specifically apply to marine discharges; thus this criterion is only usable as a guideline. The expected levels of fecal coliform bacteria that may reach Green Beach, the only known recreational use of Suez Bay, from a 10-m deep outfall are comparable to the value (200 MPN/100 ml) commonly used in the United State as a criterion for protecting recreational use (EPA 1986a). The probability of higher values frequently reaching Green Beach is small, given the infrequency of winds from the southeastern quadrant (Sect. 4.3.2.1) and the conservative estimates used in the analysis (Dames & Moore 1990).

If the decay rate is lengthened to a T^{90} of 12 hrs, the fecal coliform counts noted above as a first approximation would be increased to 7300 MPN/100 ml at the shoreline for the 5-m deep outfall and 3400 MPN/100 ml at the shoreline for the 10-m deep outfall. The levels calculated for the 10-m deep outfall remain within standards established by Law 48 for streams and drainage waters. It is important to note, however, that these values assume a linear die-off rate, whereas the actual die-off rate may be initially higher. Thus, these values remain conservative estimates of what may reach shore.

Finally, it must be noted that the probability of the wastewater plume reaching shore is low. Prevailing winds are from the northern quadrant, with winds from the southeastern quadrant occurring 13% of the time on an average annual basis. These latter winds are most likely to occur in the winter and early spring, when recreational

use of Green Beach is probably at its lowest. During the summer, the winds are at their strongest and predominantly from the north-northwest.

Coliform bacteria have been used by public health officials for several decades as a measure of water quality and potential impact on human health. The actual concern for public health, however, is not associated with coliform bacteria, but with viruses and pathogens that are frequently found in human waste. Coliform bacteria are readily detected by simple laboratory techniques, whereas viruses and other pathogens are not. Thus, coliform bacteria, particularly fecal coliforms, have been used as indicators of potential presence of fecal matter and, therefore, pathogens found in human wastes. Using these organisms as indicators, discharge via a 10-m deep outfall offers a significantly greater degree of protection of human health in the nearshore zone.

In the past decade, however, it has gradually become recognized that survival of viruses is often greater in marine waters than in fresh water. Furthermore, it appears that standard methods for measuring survival of fecal coliforms in marine waters may be significantly over-estimating die-off rates (Brayton et al. 1984). In partial response to these problems, EPA (1986a) has recommended that the coliform indicator be replaced with enterococcus (fecal streptococci) bacteria, based on the work of Cabelli (1983) and others. This recommendation has not yet been widely accepted. Consequently, analysis of human health concerns in this EA (Section 4.9) focuses on some of the non-coliform pathogens associated with wastewater discharge.

4.3.2.3 Toxic Materials

Information on known toxic pollutants in Suez wastewater is limited to data on cadmium, copper, lead, mercury, nickel, and zinc. A fertilizer plant near the proposed WWTP site, oil refinery facilities along the north shore of Suez Bay, and port facilities at Port Tewfiq are major industrial activities in Suez that may generate significant levels of toxic materials. Available information indicates that these industries are not discharging to the WWTP; rather, they are discharging directly to Suez Bay (El Sayih, pers. comm.). Present plans do not call for connecting these facilities to the proposed WWTP collection system Thus, the probability of significant loading of toxicants to the WWTP from existing industrial facilities is not high.

Information on the performance of the proposed aerated lagoon treatment method with respect to removal of heavy metals during the treatment process is lacking. In contrast, information is widely available in the US literature regarding performance of trickling filter and conventional activated sludge treatment systems (Table 4-1). If properly operated, an aerated lagoon system is expected to remove metals at a rate at least comparable to a trickling filter system, and best professional judgment suggests perhaps as good as a conventional activated sludge system (Bishop, pers. comm.).

Table 4-1. Heavy metal removal rates.

	TF[a]	CAS[a]	1° + AL [b]
Cadmiun	84%	10 - 92%	18 - 80%
Copper	75%	70 - 82%	74 - >96%
Lead	77%	46 - 90%	36 - 89%
Mercury	49%	50 - 86%	86 - 93%
Nickel	10%	9 - 32%	0 - >91%
Zinc	73%	71 - 80%	0 - 96%

a: EPA 1982; TF: Trickling filter; CAS; conventional activated sludge; 1°+AL: primary clarifiers with oxidation ponds.

b: San Francisco Bay Regional Water Quality Control Board, unpubl. data for primary clarifiers and oxidation ponds at Napa, California.

The presence of algae, which are known to sequester metals in cellular tissues, will significantly alter the performance of an aerated lagoon system with respect to solids and heavy metals removal. The presence of algae will determine whether the aerated lagoon system will be more comparable to a trickling filter treatment system or a conventional activated sludge treatment system. To limit algae in effluent, the proposed polishing lagoon will include multiple outlets with submerged drains. These do not draw algae from the water surface or shoreline. Thus, algal growth is not expected to adversely affect effluent quality.

Metals removal rates are available from a partially comparable oxidation pond treatment system in Napa, California (Table 4-1). The Napa treatment plant differs from the proposed Suez system in flow rate (33,700 m^3/d at Napa; 130,000 m^3/d at Suez in 2005), number of ponds (4 at Napa; 3 at Suez), and in that approximately 22,700 m^3/d of the flow at Napa receives treatment in primary clarifiers before treatment in oxidation ponds. The data from Napa, nevertheless, may be used to indicate performance as compared to a trickling filter system.

Heavy metals concentrations for raw sewage (influent) at Suez are reported in Table 4-2. For analytical purposes, we conservatively estimate that the percent removal of heavy metals will be comparable to a trickling filter system, with the exception of mercury. Data from the Napa WWTP indicate the aerobic lagoon process may be significantly better (Table 4-1) for removal of mercury. The analysis summarized in Table 4-2 indicates that both 5- and 10-m deep outfalls provide effluent concentrations at the edge of the zone of initial dilution that meet Decree 9 (Law 93) standards (Table 1-2) with respect to heavy metals, i.e., 5 ppm total metals (= 5,000 ug/l). In comparison to marine water quality criteria for chronic (4-day) exposure established by the US Environmental Protection Agency (EPA 1986b) for US waters, concentrations of all but mercury meet the EPA criteria.

The impact of mercury discharge on the marine environment of Suez Bay is expected to be less than significant. First, the dilution rates assumed in Table 4-2 for the two outfalls are approximately two-fold less than expected from typical current conditions observed in December 1989. Second, best professional judgment suggests that the removal efficiencies estimated for the proposed treatment process may be conservative. Third, the application of US standards for protection of aquatic biota in generally temperate ocean waters may not be applicable to the Red Sea biota. Finally, the degree of confidence in the reported concentration of mercury and other heavy metals in the raw sewage cannot be fully ascertained in the absence of information on quality assurance/quality control procedures required for "clean lab" analyses of heavy metals. Heavy metal analyses are difficult to perform with a high degree of precision. Typically, sample contamination results in reported values that are higher than those actually occurring in the sample.

Table 4-2. Expected Metals Discharge to Suez Bay.

	Raw Influent (ug/l)	Est. % Removal[a]	Undiluted Effluent (ug/l)	5-m Disch[b] (ug/l)	10-m Disch[c] (ug/l)	EPA Marine 4-Day[d] (ug/l)
Cadmium	50	84%	8	0.16	0.08	9.3
Copper	500	75%	125	2.5	1.3	2.9
Lead	200	77%	46	0.92	0.46	5.6
Mercury	30	86%	4	0.08	0.04	0.03
Nickel	90	10%	81	1.6	0.81	8.3
Zinc	400	73%	108	2.2	1.1	86
Total metals[e]	1,270		372	7.46	3.79	

a: From Table 5-1; TF unless AL demonstrably better.
b: 50:1 dilution.
c: 100:1 dilution.
d: EPA Water Quality Criteria for chronic exposure (US waters only).
e: Of those analyzed.

The presence of sulfides in the sludge will insolubilize most of the metals that settle with solids, and the removal rate from the effluent will be directly proportional to the rate of solids removal from the sewage.

If existing and future industries are connected to the municipal wastewater system at some time in the future and they include discharges of toxic materials, the potential for significant adverse effects may increase. The magnitude and significance of the impact will depend on the quantities of toxic materials and their fate in the aerated lagoon treatment process. In some cases, pre-treatment of industrial discharges may be required. The Canal Cities project includes industrial user surveys and industrial waste monitoring by the design/build contractor. An institutional development contract will also be awarded that will analyze regulations and administrative procedures concerning effluent quality and pretreatment, control, and disposal of hazardous wastes. Thus, project activities are planned to address this issue, and significant adverse impacts are not expected.

4.3.2.4 Nutrients and Dissolved Oxygen

Analysis of current water quality conditions and water quality modeling in Suez Bay indicates that Suez Bay has the capacity to assimilate the proposed wastewater discharge (Appendix B). This is expected, as winds generally will drive surface water and the effluent plume southward into the well-mixed waters in Suez Bay and the Gulf of Suez.

The proposed WWTP will reduce total BOD_5 loading to Suez Bay from sewage by 58%, even though the total volume of waste will double by the year 2005. It is not clear what net gain will accrue with respect to water quality in the immediate vicinity of El Saal Drain, however. The data from El Saal Drain suggest a significant source of BOD loading other than sewage (Appendix B). Site observations indicate that the most likely source of this additional BOD loading is a high degree of relatively recent contamination by an oil spill and the presence of significant quantities of solid waste trapped near the sampling point. If these potential sources are not eliminated or cleaned up, adverse water quality conditions will remain in the nearshore zone around the El Saal Drain outlet.

The electrical power plant near the proposed WWTP site has a seawater intake at the shoreline near the proposed site. Algal growth in cooling water pipes spurred by nutrient-rich water is a concern for power plants. For the preferred alternative, the outfall-diffuser will be over 1 km from the power station's shoreline intake. Most days the bay's circulation will carry the surfaced effluent away from shore. Data from around El Saal Drain as well as the remainder of Suez Bay indicate that the bay waters are able to assimilate the nutrient load (Section 3.4.3). Slight rises in nutrient levels around the El Saal Drain are probably attributable to less vigorous circulation

and dispersion of the nearshore wastewater plume. In the more open waters of Suez Bay and with initial dilution of at least 100:1 during the plume's rise to the surface, nutrient levels in the wastewater plume are likely to be less than currently observed in the El Saal Drain vicinity. Given that winds from the southeast quadrant occur less than 15 percent of the time, it is unlikely that nutrient levels in the wastewater plume will be high enough for sustained periods to alter algal growth in the power station's cooling system. The preferred alternative should not have a significant adverse impact on the power station's cooling water system.

The Institute for Oceanography and Fisheries (IOF) Research Station plans to construct in the near future a marine water intake to supply its research tanks. The station's engineer (Abdullah, pers. comm.) indicated that the intake is expected to be located directly in front of the research station, with a pumping capacity of 100-200 m^3/day. Assuming that the intake is located at least 200 m but not more than 400 m from shore to reach sufficiently deep water, the intake might be 1 km due west of the 10-m outfall. East winds may occasionally blow the plume towards the shore. At this distance, the bulk of the effluent will have reached the surface; however, some of the finer particulates in the wastewater plume still may be settling out at this distance. Therefore, there is a possibility of an occasional adverse impact on water quality of the IOF Research Station's proposed seawater intake as a result of settling particulates.

4.3.2.5 Summary of Water Quality Impacts

Adverse water quality effects in Suez Bay are not expected under the proposed alternative. Treatment and discharge of the wastewater offshore are clearly improvements over the present situation. Heavy metal, BOD, and nutrient loading are not expected to have a significant adverse impact on the environment at concentrations and total loading expected in 2005, unless existing and future industries are serviced by the new WWTP. Risk from industrial discharges are being addressed in other activities of the Canal Cities project. Although some uncertainty remains regarding the levels of human pathogens in the effluent, wind and current conditions generally will not be conducive to bringing the wastewater plume to shore at areas of known recreational use during the summer. Conservative analyses indicate that the levels of fecal coliforms meet Law 48 criteria following initial dilution around the outfall. Occasionally, the wastewater plume may be blown to the east, where impacts could occur on the quality of water at a proposed intake for the IOF research station.

4.4 Marine Resources

Construction and operation of the wastewater treatment plant should not produce any significant adverse impacts on the marine resources of Suez Bay. The major positive impact will be the elimination of discharge of raw sewage effluent to the

bay. Consequently the overall quality of marine resources in Suez Bay should improve slightly, especially near the El Saal Drain.

A decrease in nutrient loading will occur upon implementation of plant operation. The decrease in nutrient loading should produce, if any, only minor decreases in phytoplankton (primary) production since the system is presently light (and possibly turbidity) limited. Zooplankton populations should remain relatively stable, perhaps slightly increasing near the El Saal Drain as a result of improved water quality in the nearshore zone.

Benthic faunal populations in the nearshore zone should become healthier with an improvement of water quality. Significant decreases in organic loading will occur, and aerobic conditions are expected to slowly re-occur in nearshore sediments. The level of pathogenic bacteria retained by bivalves as a result of raw sewage effluent should decrease, although there still is the potential for heavy metal retention from other sources. Finally, the quantity and distribution of amoebic cysts around El Saal Drain should be abated.

The preferred alternative (10-m outfall) will provide better effluent dispersion and dilution as compared to the other alternatives. There will be a significantly lower concentration and mass loading of settleable solids than exists in the present situation around the El Saal Drain. Therefore, the preferred alternative should provide an improvement, as opposed to a degradation, of the bay's sediments due to reduced particulate size and concentration. This theoretical improvement, however, would occur if the outfall sites were the same for the "before" and "after" scenarios. In actuality, the new outfall is at a presently non-impacted area.

Benthic communities respond to increased wastewater discharge in several ways. Biomass in the vicinity of the outfall will often rise in response to organic enrichment, unless toxic chemicals are also present in the wastewater or organic loading is too high and causes anoxic conditions. This rise in biomass is often accompanied by a shift in community dominance from above-surface suspension-feeders to below-surface deposit-feeders (Mearns and Greene 1976; Word et al. 1977). The degree of these changes is inversely related to the concentration of organic matter in sediment, which is directly proportional to the rate of discharge of suspended solids.

For large municipal outfalls in deeper, better-flushed, temperate waters, models have been developed to predict these changes in benthic communities in broad terms (Word 1979a, 1979b). These models predict, for example, that benthic communities in an area of 0.07 km^2 would be degraded and an area of 1.9 km^2 would be changed by mass emission rates of 16,300 mt/yr suspended solids. In contrast, the Suez treatment plant will emit 2,370 mt/yr suspended solids. Although it is not clear whether these models are applicable to conditions in Suez Bay, they suggest that the impact on benthic communities at Suez is likely to be highly localized. Adverse effects (degraded conditions) are expected to occur over only a small area of bottom around the outfall,

if at all. The most likely scenario is an increase in biomass around the outfall with a change in the dominant organisms to below-surface deposit feeders.

Excavation of trenches and burial of outfall pipe will cause turbidity in the construction zone, which will be noticeable in the construction area because natural turbidity is not high. Localized short-term reductions in phytoplankton productivity may occur. Because these reductions are expected to be localized and short-term and because Suez Bay does not appear to support a biologically rich marine community, ecological impacts of construction-related turbidity are expected to be less than significant.

Construction of the wastewater outfall will impact benthic organisms within the construction right-of-way. Disturbance of this type is expected to severely disrupt benthic communities in a swath 20-40 m wide along the outfall corridor. Once construction is completed, benthic organisms are expected to begin recolonizing disturbed areas. Many benthic species, (e.g., worms, small crustaceans) have short life histories, and healthy populations of these organisms may be established in disturbed areas within 1-2 years. Some species, however, are long-lived and slow-growing (e.g., clams, seastars), and establishment of healthy populations of these organisms may require 5-10 years. The impact of these changes, however, is expected to be less than significant because the area of disturbance is small (<0.1 km^2) compared to available habitat in Suez Bay. Furthermore, sketchy information from Suez Bay suggests that benthic biota are neither diverse nor abundant (Appendix B).

If rock ballast is used to stabilize and protect the outfall pipe, a different habitat type will be provided in part of the disturbed area. This new habitat will serve as shelter and substrate for a different community of benthic marine species. This new hard-bottom habitat is likely to influence soft-bottom (sand or mud) community composition and food webs within several meters on each side, similar to the effects of offshore oil platforms (Wolfson et al. 1979) and artificial reefs. Since the majority of benthic habitat in Suez Bay appears to be soft-bottom, the new habitat has the potential of increasing diversity of benthic communities in Suez Bay. The impact on the ecology of Suez Bay is expected to be less than significant, and probably slightly beneficial.

The treatment plant should substantially reduce the incidence of fish that are harboring human pathogens associated with sewage effluent. The adverse impacts of heavy metals in raw sewage on egg, larval, and juvenile stages of fish populations also should be lessened with the commencement of treatment plant operations. In terms of heavy metals (Table 4-2), the preferred 10-m outfall alternative lowers the concentration of all heavy metals to within acceptable exposure limits established by Law 48 as well as the US Environmental Protection Agency (EPA 1986b) chronic criteria for marine waters. It should be noted that these EPA marine criteria are nationwide US standards established by studies on organisms from predominantly temperate seas, and are only useful as guidelines in this document. The preferred

alternative will reduce both the potential for fish to bioaccumulate heavy metals in the vicinity of El Saal Drain as well as in the vicinity of the 10-m deep outfall by reducing their level of exposure in these areas. An overall improvement, albeit slight, in fish health should be realized from the preferred alternative.

4.5 Terrestrial Resources

The new wastewater treatment plant, which may eventually occupy the whole 960 feddans outlined for the project, will have long-lasting ecological effects on the landscape of the area and will have its greatest impact on migrant paleoarctic birds. Some of the changes will be unfavorable to wildlife, while others might be beneficial. The net impact on wildlife resources can be assessed by looking at the main changes that will take place: the destruction of an existing natural habitat; the creation of a new man-made habitat; and the change in the quality of domestic effluent discharged to Suez Bay. The latter in particular is expected to be a significant beneficial impact for shorebirds.

4.5.1 Loss of Existing Habitat

The existing habitat at the designated WWTP site is of little ecological value. No unique flora or fauna are found on the site, and similar resources are extensively available elsewhere in the Eastern Desert. Moreover the "natural" habitat on the site has already been severely modified by the dumping of solid waste. Thus no significant loss will be encountered by further alteration of the landscape of the site.

4.5.2 Creation of New Habitat

While it is relatively easy to know and assess the natural resources which will be lost at the proposed site of the treatment plant, it is difficult to accurately predict the new landscape which will emerge after the new plant is operational. Theoretically, a habitat resembling that at the existing treatment plant would be created, attracting a similar fauna. But judging from the design details of the planned treatment and sludge drying lagoons (e.g., greater depth and surface area), it is expected that a very different habitat will be created at the new plant. The new habitat is likely to resemble that established at the Tenth of Ramadan treatment plant, which, 10 years after its construction, now holds mature *Typha* and *Phragmites* marshes. The outcome will largely depend on the final design details as well as the future maintenance and management practices (e.g., whether vegetation will be allowed to establish, how long sludge will be left in drying lagoons). These factors will influence the type of impact the proposed treatment plant will have on wildlife resources.

4.5.2.1 Possible Adverse Impacts

As is the case with the old treatment plant, the new plant will attract many migrating birds, particularly waterbirds and soaring birds (birds of prey and storks). Judging from the geographic location of the planned new plant, the treatment and sludge lagoons will fall exactly on the migration route of the soaring birds (unlike the old plant which is a little out of the way). Thus, the new plant will have an even greater potential to attract these birds. Because of the closer proximity of the new plant to the marine environment, a greater attraction to sea birds and shorebirds is also predicted.

One problem observed regularly at the existing treatment plant is the occasional mortality among birds of prey which land at the plant to rest, drink, or feed. Some birds apparently drowned while drinking; others were found dead in the general vicinity of the plant. On a single day in May 1981, 5 dead steppe buzzards (*Buteo buteo vulpinus*), one dead kestrel (*Falco tunninculus*), and one dead and one dying steppe eagle (*Aquila nipalensis*) were found at Suez. These birds were not all found in the vicinity of the existing treatment plant, but the cause of death was tied to the treatment plant as all the birds had sludge on their legs and feathers; the birds appeared to have been poisoned (Baha el Din, unpubl. data).

Another problem related to sludge is that mentioned in the October 1989 issue of *Cairo Today*, which describes how white storks (*Ciconia ciconia*) were trapped and died in wet sludge at the drying lagoons of Sharm El Shiekh wastewater treatment plant in the South Sinai (Adams 1989). The sludge, which was described as having the consistency of "hot tar," trapped an estimated five to ten storks per day. Furthermore, many of the storks which fed and rested in the vicinity of the treatment plant were dying, not from disease or poisoning as was thought, but from ingesting solid waste items (such as plastic bags, etc.) which clogged their digestive system. Undoubtedly the storks found these items floating on the surface of wastewater and sludge and mistook them for food items (Adams, pers. comm.). A West German scientist has conducted additional investigation at the Sharm El Sheikh WWTP. This investigation has confirmed that the sludge lagoons act as a trap for migrating storks (Kinzelbach pers. comm.), and has recommended that the German government finance a new WWTP which will have no open water surfaces.

The possibility of similar problems with sludge drying beds at the new Suez treatment plant is conceivable. Suez falls along one of the most important spring migration routes for storks. Although storks are not an endangered species, they are of popular interest in Europe and declines in numbers have been noted with public concern. Large numbers of storks have been seen on many occasions resting and foraging at the existing Suez treatment plant, although none were noted having trouble with the sludge, perhaps because the drying lagoons were shallow. At Sharm El Sheikh, the sewage treatment facility consists of several lagoons, some of which are about 2 m deep. The proposed sludge drying lagoons at Suez will be about 1 m deep,

and the sludge drying lagoons at the existing Suez WWTP are about 0.4 m deep. It may be that shallower sludge drying lagoons pose less of an effective trap for storks and other wading birds that land or walk into the drying sludge. Based on proposed operation of the Suez facility, the depth of the sludge in the Suez sludge drying lagoons is not likely to be more than in sludge drying beds at the existing plant. Thus, the risks to storks are not likely to be great at Suez, contingent upon operation of the sludge lagoons as proposed.

Additional analysis of the situation at Sharm El Sheikh also indicates that one of the most important differences between Sharm El Sheikh and the Suez plant is the significant increase in oils and grease in the Sharm El Sheikh lagoons as a result of recent expanded growth in sewage flows from tourism facilities (Kawata, pers. comm.). Scum has formed in the primary basins that contains food scraps as well as plastic items; the scum developed because of heavy loading of oil and grease combined with lax operation and maintenance. It is likely that storks dying in the vicinity of the plant (i.e., deaths not attributable to entrapment in sludge) ingested plastic items found among the food scraps in the primary lagoon scum.

Since there are important difference between the treatment system in Sharm El Sheik and the proposed design and operation of the Suez WWTP, significant adverse impacts are not expected. An appropriate monitoring program can be instituted (Chapter 7) to ensure these problems do not arise, or recommend mitigative measures in the unlikely event these problems do arise. Although screening facilities are planned that will remove floating solid waste items such as plastic bags, solid waste problems are ubiquitous in Egypt, and it would not be surprising to have harmful objects blown into or thoughtlessly dumped into the lagoons. Proper maintenance, therefore, is imperative in preventing these problems. The design/build contractor will develop an operations and maintenance manual and train WWTP staff in procedures that can eliminate these problems.

The Suez WWTP will be a very prominent aquatic habitat in the otherwise dry landscape on the west side of Suez Bay. In the spring, it will be the first encounter some migratory birds will have with an aquatic habitat after their departure from Sudan and Ethiopia. The situation, however, may not be as severe as at Sharm El Sheikh because of differences in species and geographic location.

Other problems that might arise from the mere presence of large numbers of birds in the area include hunting. Whimpfheimer et al. (1983) report several incidents of bird shooting at Suez where large concentrations of birds were found. Species shot included storks, birds of prey, and waterbirds. The use of pesticides to control insects at the treatment plant could be hazardous to birds and other wildlife. Soaring birds attracted to the new treatment plant might also suffer casualties by colliding with existing high-tension power lines running through the planned treatment plant site (Avery 1978). A similar situation exists at Sharm El Sheikh Finally, raptors that use

power poles are subject to electrocution with certain types of insulator design (Gilmer and Wiehe 1977, Avery 1978).

It should also be noted that many of the birds (particularly soaring birds) which interrupt their migration to use suitable habitats for resting or feeding during their passage are usually exhausted and vulnerable. It is only a natural process that some of these birds would die on their migration route. On the other hand, the treatment plant might act as a trap for some which would have been better off continuing their voyage.

Most of these potentially significant adverse impacts can be reduced to less than significant levels by proper operation of the treatment plant and appropriate mitigation measures (Chapter 7). Failure to implement and enforce these measures, however, may result in significant adverse impacts on migrating bird species.

4.5.2.2 Beneficial Impacts

In light of the severe loss of "natural" wetlands in the vicinity of Suez (and for that matter everywhere else in Egypt) in recent years, the new treatment plant can be regarded as a valuable alternative wetland habitat that could be beneficial to both resident and migrant waterbirds (depending on water quality and maintenance practices). Resident waterbirds such as spur-winged plover (*H. spinosus)* and Kentish plover (*C. alexandrinus)* will benefit the most from the new habitat. If a reed swamp is established, species such as purple gallinule (*P. porphyrio)* and moorhen (*G. chloropus)* will benefit. Insect-eating migrant waterbirds such as white-winged black tern (*C. leucopterus)* and black-headed gull (*L. ridibundus)* as well as redshank (*T. totanus)* will also benefit from the new habitat. Proper design and maintenance of the WWTP and strictly enforced prohibition of hunting will also offer beneficial resting habitat to migrating birds.

Other wildlife typically inhabiting agricultural areas, such as red fox (*V. vulpes)* and Egyptian mongoose (*H. ichneumon)* as well as rodents, will find a new habitat to colonize at the new WWTP.

4.5.3 The Fate and Quality of Effluent

The location where effluent from the treatment plant will be discharged in Suez Bay is of minor significance with regards to wildlife, but the further offshore the effluent will be released the less chance that intertidal and shallow subtidal benthic fauna, the main food for the thousands of waders wintering at the bay, will be contaminated. At any rate, the anticipated improvement in the water quality over the current situation overrides any possible minor adverse effects on wildlife resources.

The effect of the effluent from Suez on the health of birds is not known; however, poisoning and disease cannot be entirely ruled out. In central Europe every year, tens of thousands of ducks, gulls and waders fall victim to botulism resulting from use of polluted lakes, rivers, and canals (Diamond et al. 1987). Botulism organisms appear to flourish in oxygen-poor water bodies. A small potential for oxygen-poor water in the complete mix and partial mix lagoons exists if the aeration system fails for more than 1-2 weeks. This time frame, however, should be ample to effect repairs on the aeration system. Thus, this potential impact is not expected to occur if proper operation and maintenance are carried out.

4.6 Geology and Soils

4.6.1 Terrestrial Geology

Construction of the proposed WWTP and the facilities connecting it to the wastewater collection system will result in disturbance of surface and near-surface soils. Grading and trenching activities during construction will subject freshly exposed fine sands and silts to the erosive forces of winds that are common in the area. The impact, however, is not expected to be significant, because the soil and geological features in the area are neither unusual nor valuable as a scientific or economic resource.

4.6.2 Marine Geology

Impacts to the marine geological environment caused by the placement and operation of a submarine outfall may occur because of: a) interruption of normal sediment transport patterns in the littoral zone; b) displacement of the soft sediments of the floor of the bay; and c) alteration of the character of seafloor sediments because of deposition of discharged solids around the outfall.

Submarine outfalls are commonly buried through the littoral zone and laid on the seafloor outside of the littoral zone. Disruption of normal littoral transport of beach sediments would occur during construction, and depending on whether the outfall conduit was buried or exposed across the beach, may also occur over the lifetime of the structure. Such effects during the time of construction would be temporary and insignificant. If the discharge conduit is left exposed across the beach and nearshore zone, impounding of sediment on the upstream side of the structure may result in starvation of downstream beaches, which may in turn accelerate coastal erosion. Because of several factors, however, that possible effect is considered unlikely and insignificant; those factors include the low wave energies that are believed to occur in Suez Bay, the paucity of sand beaches in the vicinity of the planned outfall, and the apparent absence of similar impacts near existing structures which have been built

across the littoral zone (i.e., the intake channels for the power generating station and the Suez Petroleum Company refinery).

Marine sediments on the floor of the bay may be redistributed during construction activities, either by trenching or filling, or by placement and movement of construction vessel anchors. These impacts are considered adverse but are not significant to the geological environment.

The grain size distribution and chemical character of marine sediments in the vicinity of the outfall may be altered by deposition of solids discharged through the outfall and diffuser system. While such alternatives may have impact on the benthic biota who live on or in the sediments, it is not considered significant to the geological environment.

4.7 Groundwater

The risk of groundwater contamination by wastewater is low. Project design includes lining the wastewater lagoons with an impermeable barrier, thereby reducing percolation of wastes into the soil in order to protect the underlying soil structure and cohesion. Settled solids should rapidly reduce infiltration through any small flaws or gaps in the barrier.

Furthermore, preliminary observations indicate that groundwater under part of the site is already contaminated. Finally, the groundwater is very saline and is of little value as a source of irrigation or drinking water. Thus, there are no known beneficial uses, and significant adverse impacts are not expected.

Soil conditions in the Suez area, combined with a shallow, saline groundwater table, result in high corrosion action on certain types of buried pipe. This may be a source of some of the observed problems with groundwater contamination and oil spills along the proposed sewer trunk and force main corridor. Over time, the proposed new underground force main and trunk line facilities could become sources of groundwater contamination if measures are not taken to reduce the risk of corrosion.

4.8 Land Use

4.8.1 General

The preferred alternative better serves Suez's land use plans and environmental goals than the no-action alternative of treating wastewater at the existing site and discharging it into the El Saal Drain. As discussed in Section 3.9, long range land use plans call for cleaning up several stretches of the bay shore. The city already has restored much of the inner harbor shore, and beach cottages have been built at Port

Tewfiq. Ending sewage discharge from the El Saal Drain will be a necessary first step to cleaning up the 1-2 km of beach around its mouth. But by itself, improved wastewater treatment and disposal probably will not render the inner harbor and industrial zone shore safe for public swimming. There are too many other sources of pollution. Tourist facilities with ocean swimming are better located on the Gulf, below Ras Al Adabiya.

4.8.2 Existing Treatment Plant Site

The most important impact of the preferred alternative on the area around the existing plant and the El Saal Drain is that it should bring an end to effluent discharge into this drain. The nuisance to those living along it will be eliminated, along with the many aesthetic and human health problems with open-canal discharge into the bay.

Goats and sheep are presently grazed along the El Saal Drain by people living in the nearby informal housing. Elimination of raw sewage flows in the drain will significantly reduce public health hazards associated with this practice.

Section 3.9 pointed out that expanding wastewater treatment at the existing site conflicts with residential land use in the area. Adopting the preferred alternative may not result in a shutdown of the existing plant, but it will remove incentives for expanding it. Converting the existing site to another more suitable use, or at least not expanding it, will be a positive land use impact of choosing the preferred alternative.

Adopting the preferred alternative raises the issue of what to do with the existing treatment plant. A new, interim treatment system with two anaerobic lagoons (205,000 m^3 total volume) and four facultative lagoons (443,000 m^3 total volume) will begin operation this year. The preferred alternative's proposed new plant will have sufficient capacity to meet wastewater flows through 2005. It will render the existing plant superfluous for about 10 years. The facilities nearing completion at the existing WWTP site consist of anaerobic and facultative lagoons that can treat about 14,000 m^3/d to meet Law 48 BOD and TSS standards with only minimal modifications. With higher volume, ability to meet these standards declines.

Abandonment of the existing plant or putting it to some new use will have environmental impacts that are the direct and indirect result of choosing the preferred alternative. The site's ultimate fate will be an Egyptian Government decision, made most likely at the Governorate level. Current plans at the Governorate level are to continue to partially treat some of the wastewater at the existing WWTP, with final treatment and disposal occurring at the proposed new facility (El Sayih, pers. comm.). This option eliminates waste discharge to El Saal Drain, but continues wastewater treatment near an area of housing and industrial expansion. This option is not part of the project proposed by USAID.

With continued operation of the existing plant, odor and other nuisance problems are likely to remain in the vicinity of the existing WWTP. These problems are expected to be more noticeable as residential and industrial expansion continues in the neighborhood. These problems are likely to be more severe for people located to the south and southeast of the existing site, as they will commonly be subject to odors carried by prevailing winds. Residential construction is now occurring approximately 1 km to the northeast, and a park is under construction about 1 km to the north. To the north and northeast, odors from the WWTP are likely to be masked by refinery emissions.

A benefit of the Governorate's proposed use of the existing plant is that wastewater treatment capacity remains available beyond the year 2005 with a facility that is kept operating in the interim. Furthermore, nearby pilot aquaculture and agriculture re-use operations underway by the Institute of Oceanography and Fisheries can use the wastewater from the existing plant in their studies of feasibility of re-use of the effluent. This pilot project is located on the west side of El Saal Drain, just north of the west edge of the existing WWTP site, and is expected to begin operations in 1990.

4.8.3 Proposed Treatment Plant Site

In general, the proposed site is suited for a wastewater treatment plant; it is sufficiently distant from the urban center and it is located in a nonresidential zone. Use of the proposed site would require some adjustment of the draft long term master plan for the area. The draft master plan's bypass road can be accommodated at the rear of the site, but a crossover road cutting through the site and linking the proposed bypass to the coastal road cannot. This crossover road would require realigning or elimination.

Wastewater discharged offshore from the outfall-diffuser will not affect the planned tourist development 5-7 km south at Ataqa. Figure 3-14 shows "coastal reclamation" along the shore in front of the plant, which generally means cleanup and removal of debris along the shoreline and improvement of aesthetic conditions. As described in Section 4.3, the wastewater plume from the outfall-diffuser will circulate toward the shore infrequently, primarily in the winter. Swimming directly in front of the treatment plant will not be threatened most days by wastewater.

Even though the proposed plant will be in an industrial zone, some housing occurs nearby at the fertilizer plant and fisheries research station. These residents will be affected by odors, noise, and insects at least some times of the year. Since the housing is north and east of the plant, most days of the year the predominantly north-northwest winds should blow odors away from it. The 10-30 families expected to live a few hundred meters to the east-southeast at the fisheries research station are at

greatest risk for exposure to odors. They are likely to be impacted during periods of west winds, which are uncommon but most likely to occur December-March (Figure 3-2).

On the site itself, the power and petroleum lines should pose no significant design challenges. Of great concern, however, is the potential for adverse impact of flash floods on the site. If the plant is not constructed with safeguards to prevent flood damage, flash floods could significantly damage the facilities. Furthermore, flash flood overflows of the lagoons would cause partially treated wastewater to flow through the IOF Research Station and into Suez Bay. Designers must account for flash floods from Gebel Ataqa, as have other major facilities in the area such as the power station, which has protective berms and diversion structures.

A possible land use conflict is sludge disposal and on-going quarrying operations on the western third of the proposed site. The quarry is noted on Figure 3-13 as a circular area at the western third of the site. The actual quarry excavation is about 3-4 m deep and occupies only a third of the area noted in Figure 3-13. The remaining area designated as quarry in Figure 3-13 is occupied by spoil mounds and structures used in quarry operations. The quarry site is to be used for sludge disposal. Either quarry operations will need to end, or an accommodation worked out in which sludge disposal and quarry operations are compatible.

The proposed treatment plant should be designed in a way that does not impair public access to the base of Gebel Ataqa for hiking and tourist visits.

4.8.4 Sludge Disposal

Sludge is composed of fine inorganic matter (sand and silt that are included in wastewater flows), organic matter that is difficult to digest or biologically degrade (e.g., small seeds), and a large quantity of bacterial cell biomass. The bacterial cell biomass is composed primarily of the bacteria that grow in the wastewater treatment plant and consume the organic content of the wastewater stream. In addition, sludge will include some of the pathogens (bacteria, viruses, and parasite eggs) that are able to settle out during the treatment process, and heavy metals that are adsorbed to (attached to the surface of) particulate matter that settled out. The proposed action includes drying the sludge in lagoons, then spreading the sludge in the quarry on the western edge of the treatment plant site.

Some of the land use issues that commonly are considered with sludge disposal in wetter, more temperate climates are of little concern in Egypt. These include: leaching of heavy metals and organic compounds into groundwater, movement via surface runoff into streams and lakes, and conflict with other land uses.

In Egypt, rainfall is minimal and rare, thus, organic compounds and heavy metals are not likely to be leached from sludge deposits into the groundwater, nor is sludge likely to wash away into streams or lakes unless sludge is deposited unprotected in a wadi. At Suez, the groundwater is saline and of little use for potable or agricultural purposes. Although the risk of groundwater contamination by sludge deposited on the treatment plant site is small, the impact is not expected to be significant if it were to occur because of the lack of a significant beneficial use of the water. Furthermore, the sludge is not expected to have a high content of heavy metals or toxic organic compounds because most industrial activities that generate these pollutants do not discharge to the wastewater system.

Since the proposed treatment plant site is located on a wadi draining the Gebel Ataqa, there is a clear risk of occasional flash floods on the site. If not properly protected from flash floods, sludge deposited on the western edge of the site could be washed downslope toward Suez Bay and the industrial and fisheries research facilities located along the shore. This represents a potential significant adverse impact on water quality and nearby land uses. The design/build contractor will be required to examine flash-flooding at the site and appropriately design the facility with protective berms or other devices.

Public health issues are a major concern with sludge handling and disposal, particularly in Egypt or other countries where the population displays a high rate of infection with intestinal parasites. These issues are discussed in detail in Section 5.9.8.

4.8.5 Force Main Corridors

The proposed alternative will include connection of the existing pump stations with the new wastewater treatment plant. These connections will include a gravity-flow main travelling from the existing wastewater treatment plant to a new pump station, and a force main from the new pump station to the proposed site. The proposed corridor travels along the El Saal Drain past an area of informal housing, then cuts across country along a road near the fertilizer factory, and eventually travels behind (west of) the new power plant (Figure 2-3).

Adverse impacts on land use are not expected from this construction. With the exception of informal housing near the El Saal Drain, the proposed corridor does not travel near or through established residential neighborhoods. Noise and dust problems will be a temporary problem for residents in the informal housing area along El Saal Drain. Once construction is completed and sewage is removed from El Saal Drain, odors associated with El Saal Drain will be essentially eliminated. The temporary inconvenience of construction, therefore, ultimately results in a significant improvement in quality of life for nearby residents.

Operations of the fertilizer plant and power station should not be affected by construction of the force main. Increased traffic from construction vehicles will occur on adjacent roads as long as construction is underway. The force main will cross an access road to the fertilizer plant area just south of the proposed Ataqa pump station. Construction across this road will temporarily pose a minor constriction of traffic along this road.

A second major pipeline will carry the effluent from the treatment plant to the outfall. This pipeline will cross the Suez - El Ein El Sokhna Road and travel across the north edge of the fisheries research station before entering Suez Bay. Traffic is not heavy on this road, and is dominated by trucks and other commercial vehicles. Construction of this pipeline will temporarily pose a minor constriction of traffic along the coastal highway. This is likely to be more of a nuisance than a significant adverse impact, and is not unlike many other construction and repair operations or security checkpoints along this road.

In summary, land use impacts of construction of the proposed pipelines are not expected to be significant, but could evoke temporary nuisances during the construction phase.

4.8.6 Wastewater Flow Projection

The CMC bases its year-2005 wastewater flow forecast of 130,000 m^3/day on a "low" population projection made by the GOPP's planners (Table 3-10). The low forecast assumes an overall 1990-2005 population growth rate of 3.55 percent/year, while the "high" uses the actual 1982-1986 figure of 4.35 percent/year. Choosing the high projection would have meant an additional 17,000 m^3/day year-2005 flow. Using the high population projection, the proposed plant would be designed for a year-2005 flow of about 150,000 m^3/day, 15 percent larger.

The CMC arrived at the year-2005 flow estimate by assuming the 1990 base year population would continue to discharge 246 lcd, and multiplied the 1990-2005 population growth increment by 290 lcd. The latter figure includes 215 lcd for residential/commercial use and 75 lcd for new industrial use.

As discussed in Section 3.9.4, present per capita water use, as opposed to the amount reaching the collection system, is probably about 250 lcd. The potable water treatment plant produces about 300 lcd, and not more than 20 percent fails to reach users. So far, industry uses a relatively modest share, probably under 30 lcd, but most of this does not flow into the collection system.

Since 290 lcd is higher than present use, although by how much is unclear, the higher value may compensate for any underestimate of population growth.

In reality, Suez makes extravagant use of potable water by Egyptian and international standards (Section 3.9.4). Suez's water supply and its quality are matters of growing concern. A program to get total water use down in the 200 lcd range would have several benefits, not least among them reducing the water treatment bill. Investing in reducing water wastage might prove to be a valuable component of future expansion of sewage treatment and potable water supply facilities.

4.9 Public Health Issues

The World Health Organization (WHO) estimated in 1980 that 80 percent of all disease in the developing world is related to unsafe drinking water supplies and poor sanitary conditions (Walton 1981). Experience in many parts of the world has proven that the most effective method for reducing environmentally transmitted diseases is by the provision of centrally managed engineering works such as public drinking water supplies and sewage collection and treatment facilities. The protection of public health is a primary goal of the Canal Cities Project. This section discusses the health issues relating to the proposed wastewater treatment and disposal project.

The provision of sewage collection and treatment systems will significantly improve hygiene conditions within the community. Thus, the overall impact of the project will be beneficial to public health. Care must be taken, however, to ensure that all potential health problems are avoided to the fullest extent practical. The other significant health goals for this project include the following:

- produce a treated effluent and sludge that will not transmit disease through contact with either receiving waters or consumption of food;
- protect treatment plant workers and nearby residents from pathogen exposure;
- create environmental conditions that are not conducive for the breeding of snails, flies, mosquitos and other insects which may spread disease; and
- minimize nuisance problems such as odors and noise which are often associated with these types of projects.

The following sections address the particular health issues of this project. The potential for treated effluent reuse was discussed at the scoping meetings held in Cairo and Suez (Appendix A). Although effluent reuse is not within the scope of this project, consideration has been given in Chapter 5 to the health issues of this potential disposal alternative.

4.9.1 Microbiological Water Quality Measurement and Criteria

In order to assess the health benefits and risks of exposure to contaminated wastewater, it is necessary to be able to measure the microbiological quality of the wastewater and receiving waters to establish criteria that protect potential "downstream" users. Due to the numbers of possible organisms present and the difficulties and cost of analytical procedures, the established method of assessing microbiological quality is typically by testing for fecal coliforms or some other indicator organism.

The presence of indicator organisms reflects the presence of fecal contamination and potential disease-causing organisms. Epidemiological studies have shown, however, that there is often a poor correlation between these indicators and the actual incidence of diseases (Rose 1986; Fattal et al. 1986; El Sharkawi 1986; Salas 1986; Cabelli 1989; Payment 1989). This has resulted in considerable debate over the selection of the most appropriate indicator organisms and testing procedures.

Table 4-3 presents a summary of water quality criteria for various countries (WHO 1989). It can be seen that there are considerable differences in both the actual numbers and types of microorganisms that have been implemented for this purpose. It is important to recognize, however, that all of these indicator organisms are bacteria and cannot be reliably used in monitoring survival of viral, protozoal, or helminth (parasitic worm) organisms. The significance of this information is that current methods do not satisfactorily reflect the presence of all pathogens or disease incidence rates. Care should be exercised when interpreting data from such studies.

4.9.2 Community Health Concerns

Literature reviews clearly show that wastewaters and the associated sludges generated in the treatment process contain the full spectrum of human pathogens including helminths, protozoans, bacteria, and viruses. Furthermore, there is ample evidence that exposure to these organisms, whether it be via contaminated drinking water, food, or occupational or recreational activities, can contribute to the transmission of related diseases (Rose 1986; Shuval et al. 1986b; Cabelli 1989).

Table 4-4 presents information on the various pathogenic viral, bacterial, and protozoal microorganisms, the associated diseases or symptoms, and hosts that are associated with sewage. It is significant that individuals infected with these pathogens may not display any of the associated symptoms (Shuval et al. 1986a). Table 4-5 presents a summary of similar data for helminthic pathogens and includes information on disease transmission routes and geographic distribution. These organisms are worms which live and reproduce in the intestines or blood stream of humans and in some cases other hosts.

Table 4-3. Microbiological Quality of Water Guidelines/Standards (per 100 ml)

Country	Shellfish Harvesting		Primary Contact Recreation			Protection of Indigenous Organisms	
	Total Colif.	Fecal Colif.	Total Colif.	Fecal Colif.	Other	Total Colif.	Fecal Colif.
EPA United States		14[a] 90% < 43	200[a]	90% < 400			
California	70[e] 90% < 230		80% < 1000[j] 100% < 10000[k]	200[j] 90% < 400[j]			
EEC[b] Europe			500[c] 10000[d]	100[c] 2000[d]	Fecal Streptococci 100[c] Salmonella 0/litre[d] Enterovirus 0 PFU/Litre[d]		
Venezuela	70[a] 90% < 230	14[a] 90% < 43	90% < 1000 100% < 5000	90% < 200 100% < 400			
Peru	80% < 1000	80% < 200	80% < 5000	80% < 1000		80% < 20000	80% < 4000
Mexico	70[e] 90% < 230		80% < 1000[f] '00% <10000[k]			10000[e] 80% <10000 100% < 20000	
Brazil			80% < 5000[m]	80% < 1000[m]			
Japan	70		1000			1000	
France			< 2000	< 500	Fecal streptococci <100		
Yugoslavia			2000				
Israel			80% <100[g]				
USSR					E. coli <100		
Poland					E. coli <1000		
Puerto Rico	70[h] 80% < 230			200[h] 80% < 400			

a: Logarithmic average for a period of 30 days of at least 5 samples
b: Minimum sampling frequency - fortnightly
c: Guide
d: Mandatory
e: Monthly average
f: At least 5 samples per month
g: Minimum 10 samples per month
h: At least 5 samples taken sequentially from the waters in a given instance
i: Period of 30 days
j: Within a zone bounded by the shoreline and a distance of 1000 feet from the shoreline or the 30 foot depth contour, whichever is further from the shoreline
k: Not a sample taken during the verification period of 48 hours should exceed 10,000/100 ml
l: Period of 60 days
m: "Satisfactory" waters, samples obtained in each of the preceeding 5 weeks

Source: Salas 1986 (cited in WHO 1989).

Table 4-4. Viral, Bacterial and Protozoan Pathogens in Wastewater

	Virus	Disease	Reservoir
VIRUSES	Adenoviruses	Numerous conditions	Man
	Enteroviruses		
	Polioviruses	Poliomyelitis, paralysis, and other conditions	Man
	Echoviruses	Numerous conditions	Man
	Coxsackieviruses	Numerous conditions	Man
	Hepatitis A virus	Infectious hepatitis	Man
	Reoviruses	Numerous conditions	Man & animals
	Rotaviruses, Norwalk agent, and other viruses	Diarrhea	Probably man
BACTERIA	*Campylobacter fetus* ssp. *jejuni*	Diarrhea	Animals & man
	Pathogenic *Escherichia coli*[a]	Diarrhea	Man[b]
	Salmonella		
	S. typhi	Typhoid fever	Man
	S. paratyphi	Paratyphoid fever	Man
	Other salmonellae	Food poisoning and other salmonelloses	Animals & man
	Shigella spp.	Bacillary dysentery	Man
	Vibrio		
	V. cholerae	Cholera	Man
	Other vibrios	Diarrhea	Man
	Yersinia enterocolitica	Diarrhea and septicemia	Animals & man[c]
PROTOZOA	*Balentidium coli*	Diarrhea, dysentery, and colonic ulceration	Man & animals (esp. pigs and rats)
	Entamoeba histolytica	Colonic ulceration, amoebic dysentery, and liver abscess	Man
	Giardia lamblia	Diarrhea and malabsorption	Man & animals

a: Includes enterotoxigenic, enteroinvasive, and enteropathogenic *E. coli.*

b: Although many animals are infected by pathogenic *E. coli,* each serotype is more or less specific to a particular animal host.

c: Of the thirty or more serotypes identified so far, a number seem to be associated with particular animal species. There is at present insufficient epidemiological and serological evidence to determine whether district serotypes are specific to primates and man.

Source: Shuval et al. 1986a.

Table 4-5. Helminthic pathogens excreted in feces

Helminth	Common Name	Disease	Transmission	Distribution
Ancylostoma duodenale	Hookworm	Hookworm	Man → soil → man	Mainly in warm wet climate
Ascaris lumbricoides	Roundworm	Ascariasis	Man → soil → man	Worldwide
Diphyllobothrium latum	Fish tapeworm	Diphyllobothriasis	Man or animal → copepod → fish→ man	Widely distributed, mainly in temperate regions
Enterobius vermicularis	Pinworm	Enterobiasis	Man → man	Worldwide
Fasciola hepatica	Sheep liver fluke	Fasciolias's	Sheep → aquatic snail → aquatic vegetation → man	Worldwide in sheep and cattle raising areas
Heterophyes heterophyes	n/a	Heterophyiasis	Dog or cat → brackish water snail → brackish water fish → man	Middle East, southern Europe, Asia
Hymenolepis nana	Dwarf tapeworm	Hymenolepiasis	Man or rodent → man	Worldwide
Schistosoma haematobium	Schistosome	Schistosomiasis; bilharziasis	Man → aquatic snail → man	Africa, Middle East, India
S. mansoni	Schistosome	Schistosomiasis bilharziasis	Man → aquatic snail → man	Africa, Middle East, Central and South America
Taenia saginata	Beef tapeworm	Taeniasis	Man → cow → man	Worldwide
T. solium	Pork tapeworm	Taeniasis	Man → pig (or man) → man	Worldwide
Trichuris trichiura	Whipworm	Trichuriasis	Man → soil → man	Worldwide

n/a: Not applicable

Source: Shuval et al. 1986a.

In Egypt, roundworm (*Ascaris*), hookworm (*Ancylostoma*) and *Entamoeba* are prevalent, particularly in areas with unsanitary water supplies. *Trichuris* and tapeworms (*Taenia*) are also problems in some areas. Schistosomiasis is a serious problem but is mainly associated with bathing and drinking water supplies (Walton 1981).

Recent data specifically relating to the health and incidence of these diseases for the Suez population are not available. Although many studies have been performed of these parasites in developing countries, the actual disease incidence rates are difficult to establish due to the large number of infections which do not result in visible symptoms, inability to identify some pathogenic organisms, and under-reporting. Exposure to these pathogens does not necessarily result in infection. Factors that contribute to disease transmission include:

- the number and concentration of pathogens;
- the human infective dose;
- the virulence of the disease;
- the route of exposure; and
- the individual's immunity.

These factors are influenced by the health, age, and location of the exposed population. Figure 4-1 illustrates the typical minimal infective dose for various pathogens. Of note, diseases related to parasitic and viral infections require much lower infective doses. Immunity is a particularly important factor. Many of the enterovirus-related diseases are endemic in developing countries, and most infants acquire lifelong immunity at such an early age that additional exposure does not result in any measurable increase in disease. Concurrent exposure from contaminated food, water, and poor personal and domestic hygiene may be so prevalent that further exposure due to wastewater contact may not cause additional disease (Shuval et al. 1986b).

The health risks due to poor sanitary conditions in developing countries have been identified and ranked (WHO 1989). These relative risks are presented in Table 4-6. The helminths (intestinal nematodes) are considered the highest risk due to their low infective doses, their ability to pass through many conventional wastewater treatment processes, and their persistence in the environment.

Clearly, the provision of improved sewage collection and treatment facilities will have a positive influence on community health. Careful planning of new facilities must ensure that the cycles of infection and reinfection are broken.

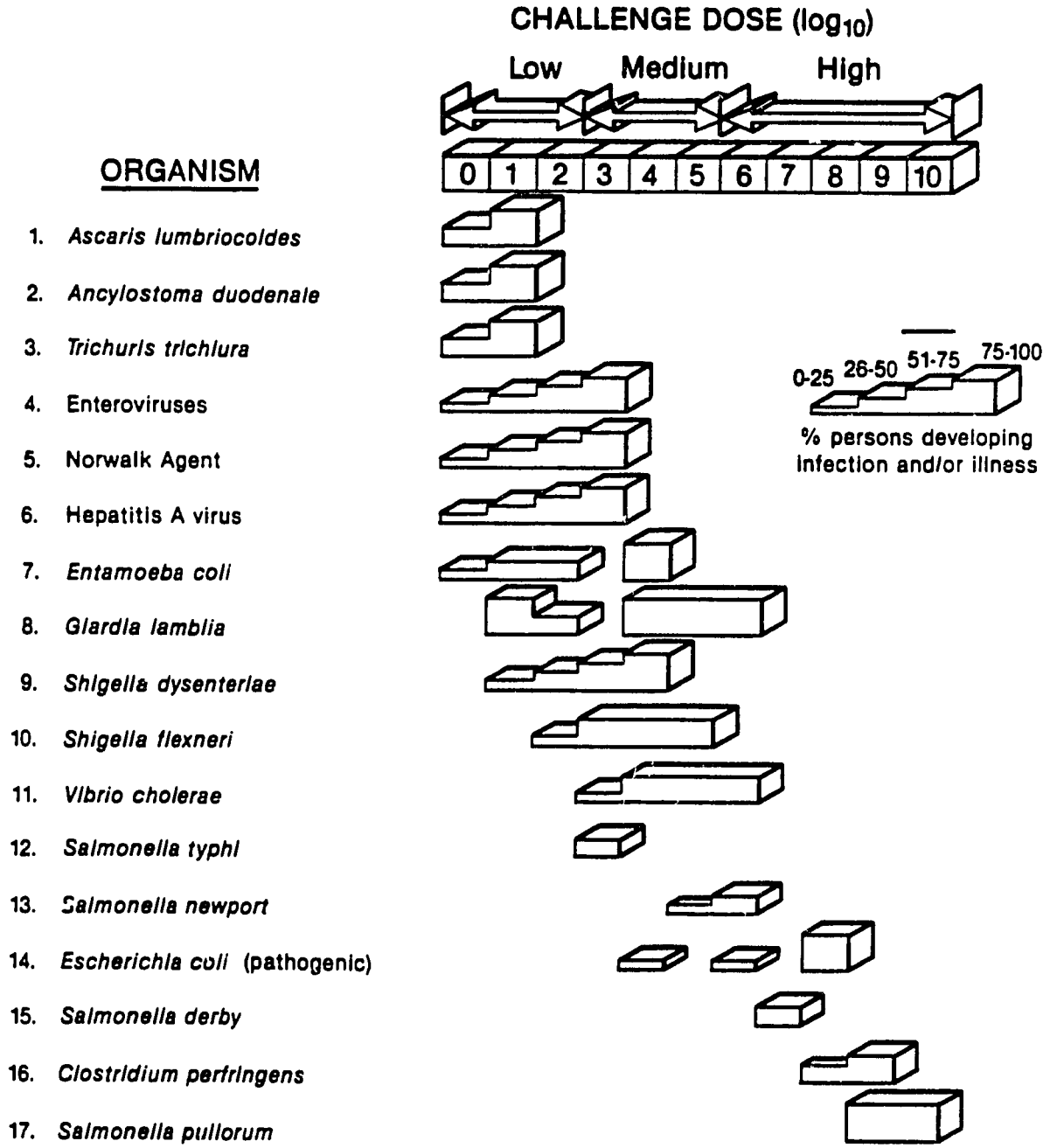


FIGURE 4-1
MINIMAL INFECTIVE DOSE OF ENTERIC PATHOGENS–
CLINICAL RESPONSE OF ADULT HUMANS TO VARYING CHALLENGE DOSES

SOURCE: Shuval et. al. 1986.

Dames & Moore

Table 4-6. Relative health risks from use of untreated excreta and wastewater in agriculture and aquaculture

Type of pathogen/infection	Excess frequency of infection or disease
Intestinal nematodes *Ascaris* spp *Trichuris* spp Hookworms	High
Bacteria Bacterial diarrhoeas (e.g., cholera, typhoid)	Lower
Viruses Viral diarrhoeas Hepatitis A	Lowest
Trematodes and cestodes Schistosomiasis Clonorchiasis Taeniasis	From high to nil, depending upon the method of excreta use and local circumstances

Source: WHO 1989

4.9.3 Pathogen Removal in Wastewater Treatment

It is important that the wastewater should be treated and discharged in a manner that will not be detrimental to the receiving environment and its users. The degree of pathogen removal that occurs during wastewater treatment varies according to the treatment process, time of treatment, and mechanism for destruction or removal of the various pathogens. This section reviews the ability of the proposed treatment plant to remove pathogens.

Helminth eggs and cysts are relatively heavy as compared to water. Removal is predominantly by settling; however, long detention times under quiescent conditions are required for complete removal. Stabilization ponds with detention times in excess of 20 days have been recommended for complete helminth removal (Shuval et al. 1986a).

Bacterial pathogen reduction in the wastewater treatment process is attributed to natural die-off, predation by protozoa, and exposure to solar radiation. High removals, usually measured via fecal coliforms, can often be achieved in wastewater treatment systems with long detention times, such as the waste stabilization ponds noted above. Effluent disinfection is normally required to maintain low bacterial counts in the effluent of activated sludge and aerated lagoon systems.

Viruses have been shown to adsorb onto suspended material. The majority of these organisms are effectively removed by floc-forming biological treatment processes, such as activated sludge processes and aerated lagoons.

Table 4-7 summarizes the fate of important pathogens during wastewater treatment and upon discharge to the environment. It should be noted that the proposed aerated lagoon system has a detention time of 11 days. Pathogen removal will probably lie between that indicated for oxidation ditch and waste stabilization systems. Design equations have been empirically developed for fecal coliform reduction but cannot accurately predict pathogen removal in new systems (Marias 1974; Sarikaya et al. 1987; Bowles et al. 1979). Direct comparisons between other systems are of value as first approximations only due to variations in location, design, and operating conditions.

Pathogen removals for the proposed aerated lagoon system are estimated to be between 95 and 100 percent (Table 4-7). Fecal coliform concentrations in the order of 10,000 to 100,000 per 100 ml could be present in the treated effluent (Middlebrooks et al. 1979). It is also reasonable to assume that complete removal of helminths and parasitic cysts may not occur. The final polishing pond provides only 5 days detention of true quiescent conditions.

Table 4-7. Summary of Pathogen Removal by Various Sewage Treatment Processes.

Organisms	Parameters	Oxidation ditch with sedimentation and sludge drying	Waste stabilization ponds 3 cells. Minimum total retention time = 25 days	Land application or slow sand filtration as tertiary treatment	Chlorination as tertiary treatment	Effluent discharged to fresh water	Effluent discharged to sea	Thermophilic digestion or composting	Agricultural application
Enteric viruses	Typical inflow Typical outflow Percent removal Final sludge	10^3-10^5/l 10-10^4/l 90-99% Contaminated	10^5-10^5/l 0-10/l 99.99 - 100%	10-10^4/l 0-10^2/l 99-100%	May survive	May survive for several weeks	May survive for several weeks	Killed rapidly at 60°C	May survive up to 5 months on soil
Salmonellae	Typical inflow Typical outflow Percent removal Final sludge	10^3-10^4/l 10-10^3/l 90-99% Contaminated	10^3-10^4/l 0-1/l 99.99-100%	10-10^3/l 0/l 100%	Eliminated	May survive for several weeks	May survive for a few weeks	Killed in 20 hours at 60°C	On soil, S. typhi may survive up to 3 months and other species for up to 1 year
Shigellae	Typical inflow Typical outflow Percent removal Final sludge	10^3-10^4/l 10-10^3/l 90-99% Contaminated	10^3-10^4/l 0-1/l 99.99-100%	10-10^3/l 0/l 100%	Eliminated	May survive for several weeks	Unlikely to survive for more than 40 days	Killed in 1 hour at 55°C or in 10 days at 40°C	May survive for up to 3 months
E. coli	Typical inflow Typical outflow Percent removal Final sludge	10^6-10^8/l 10^4-10^7/l 90-99% Contaminated	10^6 10^8/l 10-10^4/l 99.99-99.99999%	10^4-10^7/l 0-10^3/l 99.99-100%	A few may survive (regrowth likely)	May survive for several weeks	May survive for a few weeks	Rapidly killed above 60°C	Several months
Cholera vibrio	Typical inflow Typical outflow Percent removal Final sludge	10-10^3/l 0.1-10^2/l 90-99% Contaminated	10-10^3/l 0/l 100%	0.1-10^2/l 0/l 100%	Eliminated	May survive for several weeks	Unlikely to survive for more than 11 days	Killed rapidly above 55°C	Unlikely to survive more than 1 week
Leptospires	Typical inflow Typical outflow Percent removal Final sludge	Very few Very few 0% Safe	Very few 0/l 100%? -	Very few 0/l 100% -	Eliminated	May survive for several weeks	Survive for not more than 20 hours	Killed in 10 minutes at 50°C	Survive for up to 15 days on soil
Entamoeba histolytica cysts	Typical inflow Typical outflow Percent removal Final sludge	10-10^4/l 5-10^3/l 50%? Safe	10-10^4/l 0/l 100% -	10-10^3/l 0/l 100% -	Probably eliminated	May survive for 3 weeks	May survive for 3 weeks	Killed in 5 minutes at 50°C and in 1 day at 40°C	May survive for 1 week if kept damp

Cont'd
Table 4-7

Organisms	Parameters	Oxidation with sedimentation and sludge drying	Waste stabilization ponds 3 cell. Minimum total retention time = 25 days	Land application or slow sand filtration as tertiary treatment	Chlorination tertiary treatment	Effluent discharged to fresh water	Effluent discharged to sea	Thermophilic digestion or composting	Agricultural application
Hookworm ova	Typical inflow Typical outflow Percent removal Final sludge	$10\text{-}10^3/l$ $10\text{-}10^2/l$ 50-90% Contaminated	$10\text{-}10^3/l$ 0/l 100% -	$10\text{-}10^2/l$ 0/l 100% -	Will survive	May survive for several weeks	?	Killed in 5 minutes at 50°C and in 1 hour at 45°C	May survive on soil for 20 weeks under ideal conditions
Ascaris ova	Typical inflow Typical outflow Percent removal Final sludge	$10\text{-}10^3/l$ $0\text{-}10^2/l$ 70-100% Contaminated	$10\text{-}10^3/l$ 0/l 100% -	$0\text{-}10^2/l$ 0/l 100% -	Will survive	May survive for many months	May survive for many months	Killed in 2 hours at 55°C, in 20 hours at 50°C and 200 hours at 45°C	May survive on soil for several years
Schistosome ova	Typical inflow Typical outflow Percent removal Final sludge	1-100/l 1-10/l 50-99% Safe	1-100/l 0/l 100% -	1-10/l 0/l 100% -	Probably eliminated	Ova will hatch and miracidia must find snail	Ova or miracidia will die	Killed in 1 hour at 50°C	May survive up to 1 month if kept damp
Taenia ova	Typical inflow Typical outflow Percent removal Final sludge	1-100/l 0.5-50/l 50%? Contaminated	1-100/l 0/l 100% -	0.1-50/l 0/l 100% -	Will survive	Will survive for several weeks	Will survive for several weeks	Killed in 10 minutes at 50°C and in over 4 hours at 45°C	May survive on soil for over a year with sufficient moisture

Source: Lindstrom 1986

4.9.4 Health Impact of Recreational Water Uses

Analyses of the projected wastewater effluent quality and dilution with sea water have been performed (Section 4.3.2.2). These show that for an end-of-pipe fecal coliform concentration of 400,000 MPN/100 ml, nearshore concentrations are likely to exceed 200 fecal coliforms/100 ml, the EPA (1986a) recommended standard for recreational waters, but probably meet Law 48 criteria.

As discussed previously, recreational activities in the bay are restricted for security reasons and discouraged by the existing nearshore pollution from ships, oil refineries, and other sources in the bay. There is public swimming in the inner harbor, but there are no recreational boating activities at present. Based on the very limited amount of recreational activity that occurs in the bay, the proposed level of wastewater treatment appears to be adequate. The construction of an offshore outfall will improve the public health situation with respect to existing nearshore pollution; however, reduction of pollution from other sources will also be required to produce good water quality in the bay, especially near shore.

4.9.5 Health Impacts with Respect to Fishing and Shellfishing

The Institute of Oceanography and Fisheries at Suez reports that there are no shellfish beds or fishing activities in Suez Bay (Bebars, pers. comm.). It is not known if this is due to the lack of fish or disinterest on the part of fishermen because of pollution and restrictions on boating activities. The bay serves as an anchorage for ships waiting to pass through the Suez Canal. The Suez Wastewater Master Plan reported that the bay may be a spawning ground for fish in the gulf (Pirnie-Harris International 1979), but this has not been confirmed.

It does not appear that the discharge of treated effluent from the proposed wastewater treatment plant will have an adverse impact on public health from contaminated fish or shellfish due to the lack of shellfishing and confirmed fishing activities in Suez Bay.

4.9.6 Health Impacts to Wastewater Treatment Plant Operators

Workers at wastewater treatment plants are more exposed to pathogens than other groups, by either direct wastewater or sludge contact, or from the aerosols that result from the aeration process. Many studies have been conducted on these occupational groups to determine the susceptibility and incidence rates of sewage transmitted diseases (Rose 1986; Shuval et al. 1986b; Pahren and Jakubowski 1987).

In contrast to disease outbreaks associated with raw wastewater irrigation, there is no conclusive evidence that disease may be transmitted through spray irrigation of wastewater or aerosols generated during biological wastewater treatment (Rose 1986). Clark (1984) reviewed the incidence of disease associated with occupational exposure and found increased incidence of gastrointestinal and parasitic infections, especially with inexperienced workers.

Hepatitis outbreaks have often been reported among sanitation workers, but these are mostly attributed to person-to-person transmission and inadequate designation of potable water. It has been found through serological testing that although no increased risk of contracting hepatitis was observed, wastewater workers had an excess of antibodies to some of the enteroviruses (Rose 1986).

4.9.7 Health Impacts to Nearby Residents

As noted above, studies have shown that viruses and other pathogens can be transmitted considerable distances via aerosols from the site and remain viable. However, there have been no reports that this exposure results in an increased incidence in disease. As with wastewater treatment plant operators, it appears that the relatively high levels of immunity against most viruses endemic in the community either block or reduce transmission to the point where it is not measurable (Pahren and Jakubowski 1987).

The Suez Branch of the Institute of Oceanography and Fisheries is located approximately 600 m east the complete-mix basin, which is the only basin likely to generate significant amounts of aerosols. It is thought that this distance provides an adequate buffer. Furthermore, wind data collected from Port Tewfiq indicate infrequent occurrence of winds from the west. Occupants of the IOF offices and adjacent residential buildings should not experience an increased health risk.

4.9.8 Health Impacts Related to Sludge Handling and Disposal

Studies in India have shown that sewage farm workers experienced significantly higher levels of *Ascaris* and hookworm infections than other agricultural workers. In addition, a high incidence of anemia (a debilitating symptom of severe cases of hookworm infestation) was observed (Rose 1986; Shuval et al. 1986b). However, contact with stabilized sludge has not produced any observable increase in disease.

Most of the solids generated in the proposed treatment process will settle, accumulate and be stabilized in the second (semi-mixed) lagoon. The degree of stabilization achieved will depend on the mixing level, oxygen conditions, and the time between sludge removal operations. Based on preliminary calculations, it appears that sludge should be removed from the second cell every 3 or 4 months.

Sludge removed from the lagoon system will be transferred to a sludge drying lagoon system where it is expected to be stored for at least 60 days and achieve a 20 to 40% solids concentration. Dried sludge would then be removed and stockpiled for an additional 45 to 90 days, where some additional drying and pathogen die-off will occur. After storage, sludge will be disposed in a quarry located on the west end of the WWTP site.

Table 4-8 shows typical survival times of selected pathogens in soils. Survival times in sludges are similar to those indicated for soils. Studies have shown that *Ascaris,* in particular, can survive for extended periods in the environment (WHO 1989; Shuval et al. 1986a). Based on the anticipated treatment sequence outlined above, it should be assumed that some pathogens, particularly helminth eggs and cysts, may remain viable. As a result, there is the potential for reinfection within the community if farmers were to remove and reuse the sludge at this stage. The use of sludge drying beds has been found to be quite effective at inactivating eggs, although a very low moisture content (less than 5%) is required (Reimers et al. 1986). This is significantly less than the 20 to 40% solids content anticipated for the proposed plant.

Tables 4-9 and 4-10 show the presence and persistence of parasites in the sludge generated at the Alexandria wastewater treatment plant. *Ascaris* eggs, *Trichuris,* and *Entamoeba* all survived the drying process at 30% cake solids. Lime addition was also evaluated in this study, but was not effective on *Ascaris* (El-din Hassan 1988).

In summary, it cannot be assumed that the proposed sludge management system will be effective in removing all pathogens. In particular, it is likely that *Ascaris* eggs will survive the process, and use by local farmers will provide a potential for reinfection. Additional sludge stabilization is recommended (Chapter 7) if sludge is to be used for agricultural purposes. Thus, reuse of the sludge is not recommended at this time, and is not included in project design because of the public health concerns. As the project is presently designed, sludge will be disposed of on land on the western portion of the site.

4.9.9 Evaluation of Potential Disease Vectors and Nuisances

The following nuisance problems may be associated with the proposed wastewater treatment system:

- fly breeding in the sludge drying lagoons;
- snail and mosquito breeding in the polishing pond; and
- algae growth in the polishing pond.

Flies are very common in Egypt due to the climate, and materials such as sludge provide ideal breeding media (El-din Hassan 1988). Details of how the sludge drying

Table 4-8. Survival times of selected excreted pathogens in soil on crop surfaces at 20-30°C[a].

Pathogen	Survival time	
	In soil	On crops
Viruses	<100 but usually <20 days	<60 but usually <15 days
Enteroviruses[b]		
Bacteria		
Fecal coliforms	<70 but usually <20 days	<30 but usually <15 days
Salmonella spp	<70 but usually <20 days	<30 but usually <15 days
Vibrio cholerae	<20 but usually <10 days	<5 but usually <2 days
Protozoa		
Entamoeba histolytica cysts	<20 but usually <10 days	<10 but usually <2 days
Helminths		
Ascaris lumbricoides eggs	Many months	<60 but usually <30 days
Hookworm larvae	<90 but usually <30 days	<30 but usually <10 days
Taenia saginata eggs	Many months	<60 but usually <30 days
Trichuris trichiura eggs	Many months	<60 but usually <30 days

a: Source: Reimers et al. 1986
b: Includes polio-, echo-, and coxsackieviruses.

Table 4-9. Parasite Concentrations in Different Sludges at Alexandria, Egypt

Parasite	Raw Sludge	Dried Sludge*
Ascaris Eggs	+++	+
Taenia Eggs	+	N.D
Trichuris trichiura	+	+
Entamoeba coli	+++	++

* Dried sludge at "Liftable stage" i.e. 30% total solids.
Note: N.D. indicates not detected; number of plus signs indicates relative abundance.
Source: El-din Hassan 1988.

Table 4-10. Parasite Concentrations in Dry and Composted Sludge, Alexandria, Egypt.

Parasites	Wet sludge	Dried sludge liftable 15 Days	Compost 30 days	Compost 45 days	Compost 60 days
Ascaris eggs	+	+	N.D.	N.D.	N.D.
Taenia eggs	+	N.D.	N.D.	N.D.	N.D.
Entamoeba coli cysts	+	+	+	N.D.	N.D.
Stronglyloides larvae (living)	++	++++	+++	++	+

Note: N.D. indicates not detected; number of plus signs indicates relative abundance.
Source: El-din Hassan 1988

lagoons will be operated have not yet been decided, except that some form of initial decanting will remove supernatant to minimize the insect breeding potential. The sludge will dry by both drainage and evaporation.

Chemical treatment is an option for controlling insect breeding if it becomes a problem, which under these circumstances seems likely. While chemicals are effective, there are several disadvantages. First, chemicals are expensive and may not always be available. Second, persistent chemical addition to sludges enhances the natural resistance of insects to insecticides. Third, additional chemical storage facilities, chemical application equipment, and operator training are also required. Finally, some insecticides may also be hazardous to birds, particularly if not used properly. This issue may be of some concern if migrating birds use the site as resting and feeding areas.

Snail breeding may occur in the polishing ponds, but the risk of transmitting schistosomiasis is not expected to be significant. The polishing ponds are too deep to allow wading and the effluent is to be discharged offshore. The infectious cycle of man-snail-man is therefore broken. As an additional measure to minimize worker exposure, activities in the polishing pond should be restricted. Molluscides are regularly used in the Sweetwater Canal to control snail populations and could be used if necessary. These should be used only if necessary, however, as molluscides may have adverse effects on marine species upon discharge. Snail screens may be warranted if a problem develops.

Mosquito (*Culex* sp., which is not a malaria vector) breeding in the polishing ponds may present a problem. This can be controlled by spraying or possibly by fluctuating the water level in the polishing basin (Diamant 1989). The latter option may be difficult to implement in the proposed system, and the former may have adverse effects on marine species.

Some algal growth in the polishing pond will probably occur. This would have the effect of increasing the effluent solids and reducing the bacterial pathogen die-off rate.

4.9.10 Health Impacts of Chemicals and Toxic Materials

There is little evidence available to indicate that heavy metals and other toxic compounds would be present at toxic levels in the wastewater. Therefore, problems associated with these compounds are not expected. However, periodic checks should be performed on the plant influent and sludges. Careful evaluation and possible pre-treatment of discharges to the sewer from new industries should be implemented to ensure that toxic discharges do not become a problem in future.

4.9.11 Summary

From a public health point of view, the proposed wastewater treatment facilities for Suez are considered satisfactory assuming that the final effluent disposal is to Suez Bay via an outfall. The proposed action is clearly a significant improvement over the existing situation, in which virtually untreated wastewater is dumped into open drains and eventually discharged across the beach on the north shore of Suez Bay. There are, however, potential problems with the proposed sludge management system. These problems relate to the survival of *Ascaris* and other helminths, and the possibility of disease transmission to workers if sludge is improperly handled or by agricultural reuse of the sludge by local farmers. Nuisance conditions may also rise with respect to flies, mosquitos, and algae in the polishing ponds. Potential solutions to these problems are outlined in Chapter 7. Under the proposed action, agricultural reuse of the sludge is not planned; therefore, this potential problem is not expected to be realized.

4.10 Energy

The use of energy is integral to the operation of modern wastewater treatment facilities; each of the treatment options described in Section 2.7.4 will increase energy consumption (primarily as electricity) above current levels. While the cost of electricity accounts for a significant portion of the operation and maintenance (O&M) cost of each option, there is wide variability in proportion among these options. There are two principal issues with regard to energy consumption: first, the amount of energy required to operate the treatment plant (an irretrievable commitment of resources); and second, the cost associated with the use of energy.

4.10.1 Energy Consumption

There is a large difference in the estimated energy consumption between each of the treatment options considered. Annual average electric power consumption (and its equivalent in barrels of oil) is as follows:

Alternative	Annual Electricity Consumption (10^6 kwh)	Equivalent bbl oil/yr
Conv. activated sludge	14.45	8,500
Aerated lagoon	23.80	14,000
Trickling filter	5.15	3,000

The consumption of oil (as an equivalent to electricity) is calculated by assuming a production efficiency of 1,700 kwh per barrel of oil in Egypt (Ichord, pers. comm.) and 100% oil-fired generation.

As observed above, the trickling filter treatment system is expected to have the lowest energy demand of those considered and aerated lagoons the highest. The oil consumed to produce the electricity would be an irretrievable commitment of resources of at least 3,000 barrels of oil per year (under the trickling filter treatment system) and a maximum of 14,000 barrels of oil per year (under the aerated lagoon option). This would translate into a demand of 3 to 5 MW of electric generating capacity for the aerated lagoon system; less for all other options. This is well within the existing generating capacity in the area.

4.10.2 Cost-Effectiveness

The second major concern with regard to energy consumption is the cost of that energy and the impact of the cost on the paying entity. While the construction costs of the proposed WWTP are to be met by the national government with grant assistance from USAID, the costs of operation and maintenance are to be met by the Governorate. Compounding the impact of this potential obligation to meet O&M costs are the plans of the Egyptian government to remove existing subsidies on energy and to allow them to rise to a level equal to the long range marginal cost (LRMC) of generating new power (although the rate of increase is not yet clear). At present, the cost of electricity is $0.02/kwh. At this level, the wastewater department of the Governorate budgets LE 300,000 ($188,000) per year primarily to operate the collection system pumps (El Sayih, pers. comm.). Recent analysis indicate that the long range marginal cost of electricity for generation from new powerplants in Egypt is $0.066/kwh (Adler 1990). The availability of adequate funds to cover O&M costs is specifically addressed in the Grant Agreement for the Canal Cities project. A users rate study is underway to provide the necessary data to the Governorate.

A present worth comparative cost analysis was performed to determine the impact of varying the cost of electricity on the overall present worth of the aerated lagoon treatment process and technically feasible alternatives (conventional activated sludge and trickling filter treatment systems). This analysis, which is described in further detail in this section, found that:

- there is no economic difference among the three alternatives based on present worth;
- the aerated lagoon system is marginally cost effective compared to the alternatives based on construction costs; and

- o although the aerated lagoon system is more energy intensive than the alternatives, it appears to offer significant advantages as the selected plan when project features such as operational complexity, sludge management, and local personnel capabilities for O&M are integrated into the selection process.

Energy costs were varied in the analysis for this EA from $0.02/kwh to $0.10/kwh, and the impacts on the total present worth were determined. The total present worth includes the present worth costs for wastewater treatment, sludge treatment, operations and maintenance, and salvage. The life cycle analyses factors used by the CMC have been used for this analysis. These factors are as follows:

Life Cycle Period:	10 years
Useful Life of Facilities	
Structures:	30 years
Equipment:	10 years
Interest Rate:	8.875 percent

Costs for Suez were obtained from CMC (1989). The estimated total annual energy costs and estimated total annual operation and maintenance (O&M) costs over the range of energy costs are evaluated as follows:

	Total Estimated Annual Energy Costs at Indicated Rate (in thousand dollars)			
Alternative	$0.02/kwh	$0.04/kwh	$0.06/kwh	$0.10/kwh
CAS - w/o P	350	706	1,050	1,750
AL	700	1,400	2,100	3,500
TF	120	240	360	600

(CAS - w/o P indicates conventional activated sludge treatment without primary clarifiers; AL indicates aerated lagoons; and TF indicates trickling filter treatment.)

	Total Estimated Annual O&M Costs at Indicated Energy Rate - (in million dollars)			
Alternative	$0.02/kwh	$0.04/kwh	$0.06/kwh	$0.10/kwh
CAS - w/o P	1.317	1.667	2.017	2.717
AL	1.599	2.299	2.999	4.399
TF	0.991	1.111	1.231	1.471

Total estimated present worth costs for each alternative are shown on Figure 4-2 and are summarized as follows:

	Total Estimated Present Worth Costs at Indicated Energy Rate - (in million dollars)			
Alternative	$0.02/kwh	$0.04/kwh	$0.06/kwh	$0.10/kwh
CAS - w/o P	86.25	88.50	90.77	95.31
AL	77.89	81.65	86.18	95.26
TF	83.77	84.54	85.32	86.87

In comparing present worth costs, differences of less than 10-12% are usually considered to be insignificant because accuracy of estimates do not allow distinction within this range. The estimated present worth cost for aerated lagoon alternative is 7.55% less than the trickling filter at energy costs of $0.02/kwh. However, the trickling filter costs are slightly lower than the aerated lagoon costs when energy costs exceed about $0.06/kwh. The estimated present worth cost of the conventional activated sludge without primary clarifiers is about 6% higher than the trickling filter at an energy cost of $0.06/kwh and about 10.7% higher than the aerated lagoons at $0.02/kwh. The analysis indicates that the total present worth costs for all the processes examined are essentially equivalent at energy costs of $0.06/kwh. The total present worth costs for the aerated lagoon and the conventional activated sludge without primary clarifiers are about equal at energy costs of about $0.10/kwh.

Estimated life cycle costs included in the reports for the three alternative processes at $0.02/kwh are summarized as follows:

	Estimated Costs - $1,000,000			
	Construction		Present Worth	
Alternative	Cost	% Above Low	Cost	% Above Low
CAS - w/o P	87.30	16.40	86.25	10.71
AL	75.00	-----	77.89	-----
TF	86.90	15.87	83.77	7.55

Total estimated comparative present worth costs at $0.06/kwh, the estimated LRMC, for the three alternative processes are summarized as follows:

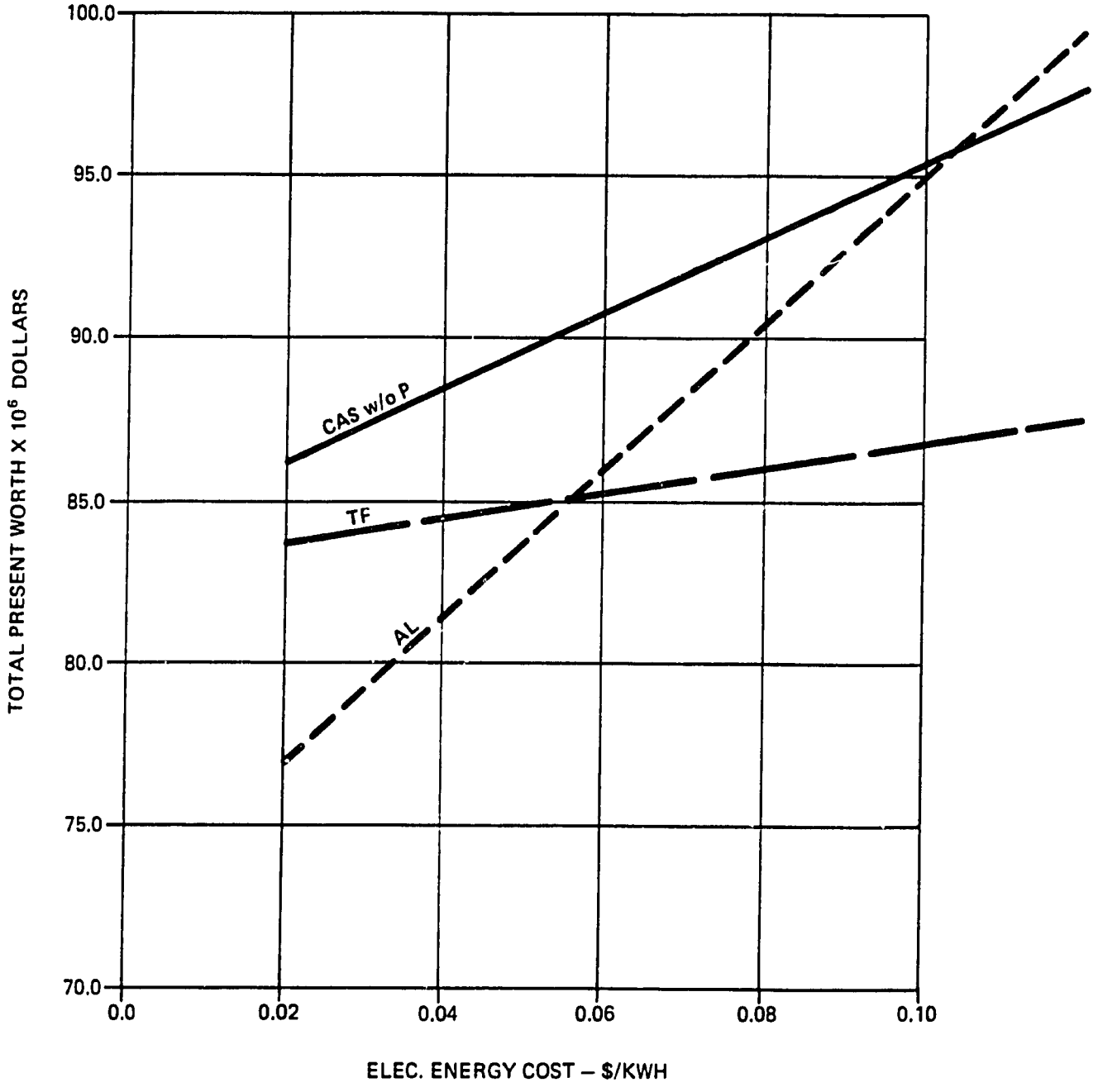


FIGURE 4-2
PRESENT WORTH COMPARISON WITH VARYING COST OF ELECTRICAL POWER

Dames & Moore

Alternative	Estim. PW $1,000,000	% Above Lowest PW
CAS - w/o P	90.77	6.39
AL	86.18	1.01
TF	85.32	-----

The foregoing comparison with respect to present worth indicates that there is no economic difference at the LRMC between the three alternatives, but the TF alternative becomes the cost effective project at an energy cost of about $0.10 to $0.12/kwh.

4.11 Air Quality, Noise, Odors

4.11.1 Construction

Winds are predominantly from the north-northwest quadrant year around (Figure 3-2), with a secondary importance of winds from the south-southeast quadrant during December-April. Northerly winds will blow dust and construction equipment emissions to the south-southeast quadrant most of the year. The facilities most likely to be impacted are the fisheries research station and residences, located about 200-300 m east and southeast of the WWTP. Although local wind conditions are not documented for the treatment plant site, wind patterns noted at Port Tewfiq by the Suez Canal Authority suggest that these buildings would be directly downwind of the treatment plant site infrequently. Adverse effects on air quality from dust are most likely during the construction of the force mains carrying wastewater to the treatment plant site and to the marine outfall. These impacts are expected to be temporary Adverse effects of dust can be significantly reduced by dust control measures during periods when local wind conditions blow dust toward the fisheries research institute.

Winds from the southeasterly quadrant are most likely to occur during the winter months, with a mean monthly maximum of about 23% in March. During these infrequent events, dust and equipment emissions will be blown towards the fertilizer factory and its residential facilities. These impacts are expected to be temporary. Adverse effects of dust can be significantly reduced by dust control measures during periods when local wind conditions blow dust toward the fertilizer factory.

Noise generated by heavy equipment during construction will be a nuisance at the fisheries research institute, and possibly at the fertilizer factory. The type of heavy equipment used for construction of the Suez WWTP is not known and will vary widely between contractors. Adverse effects can be partially reduced by ensuring that power equipment is equipped with mufflers in good repair. These impacts are expected to be

temporary, and may be further ameliorated by limiting heavy equipment operation to normal Egyptian working hours and days.

4.11.2 Operations

Operation of the wastewater facilities may generate aerosols, particularly from the full-mix aerated lagoons, and odors.

Aerosols are of most concern with respect to public health considerations. These are more fully analyzed in Sections 4.9.6 and 4.9.7. Generally, adverse effects of aerosol generation are expected to be less than significant.

Odors are most likely to be generated by sludge drying lagoons. The amount of odor will depend on the degree of stabilization achieved in the partially mixed lagoon and the water content of the sludge in the drying lagoons. If the plant aeration system fails for an extended period of time, the treatment system would gradually transform into a facultative lagoon system. Odor problems with lagoons are likely to arise if the system converts to this treatment method. There is no intention for the plant to operate as a facultative lagoon system. The aerated lagoon system is the most stable, most forgiving of plant upset, and it would take 1-2 weeks before odor problems would arise. Thus, ample time is likely available to restore aeration before odor problems arise.

As noted above, prevailing winds are expected to blow odors away from the fertilizer factory, but toward the proposed graphite factory. At present, the only facility present at the graphite factory is a wall around the property. The frequency with which winds will cause the fisheries research institute to be directly downwind of the sludge drying lagoons is not known, as there are no site-specific wind data. It is likely, however, that winds will generally carry odors and air-borne pollutants in a southerly direction toward the graphite factory site and to the port facilities and fishing harbor located 4-5 km to the south. By this point, dispersion is likely to reduce levels of odor-causing compounds to less than nuisance conditions.

Winds from the southeasterly quadrant are most likely to occur during the winter months, with a mean monthly maximum of about 23% in March. During these infrequent events, aerosols and odors will be blown towards the fertilizer factory and its residential facilities. These impacts are expected to be temporary nuisances.

4.12 Cultural Resources

As discussed in Section 3.12, the settled area of ancient Suez evidently did not extend to the proposed site for the preferred alternative. Implementing the preferred alternative should not threaten any archeological sites of importance.

The site very likely has been occupied sporadically over the centuries by fisherman and herders, and traversed by coastal roads and trails. At least a few artifacts stemming from such uses probably lie buried at the site. Without appropriate procedures for their identification and recovery during construction, they will be damaged or lost. Informal consultations with the Department of Antiquities indicates no resources are expected at the sites. Therefore, the possibility of a significant adverse impact is small.

4.13 Irreversible and Irretrievable Commitments of Resources

Resources that will be irreversibly and irretrievably consumed or lost as a result of construction and operation of the proposed project include:

- energy in the form of fossil fuels;
- cement and other materials used in construction; and
- wildlife habitat.

Of these, the loss of wildlife habitat is insignificant because the site is not good quality habitat and wildlife use is of little importance.

Consumption of fossil fuel and cement is insignificant in terms of national and regional supplies and consumption; these losses are undetectable incremental increases in local and regional use of these resources. Although the cumulative consumption of these (energy in particular) is of environmental concern on a national and global level, the benefits to public health and quality of life as a result of commitment of these resources is well worth the extremely small cumulative impact.

CHAPTER 5

5.0 ENVIRONMENTAL EFFECTS OF ALTERNATIVES TO THE PROPOSED PROJECT

5.1 Treatment Alternatives

A wide range of economic and technical considerations have been incorporated in eventual selection of the preferred treatment alternative. Some of the more important ones are described in Chapter 2. Environmental considerations have also played an important role, dating back to extensive environmental analyses conducted as part of the facilities master plan (Pirnie-Harris International, 1979) and including the Phase II Project Paper prepared by USAID (1987). Environmental consequences of some of the treatment alternatives that have been considered are briefly described in this section of the EA.

5.1.1 Site Selection

With the exception of treatment and disposal via the rapid infiltration process, alternative treatment methods would occur on the site currently proposed for the aerated lagoon treatment system. Therefore, impacts associated with existing wildlife resources on the site and land use in the vicinity are generally comparable to those associated with the preferred alternative (Chapter 4).

5.1.2 Trickling Filter

Trickling filters consist of a stationary medium which provides surface area and space for air and water movement. A film of bacteria grows on the stationary medium, and wastewater is allowed to trickle over the surface. The bacteria convert organic wastes into cell tissue.

The greatest environmental differences between the preferred alternative (aerated lagoon treatment) and a trickling filter treatment system involve:

- o migratory bird use of the treatment plant site,
- o operational reliability,
- o energy consumption, and
- o water quality.

5.1.2.1 Impact on Waterfowl and Migrating Birds

A trickling filter system will entail significantly less area of open water than the aerated lagoon system. Thus, the attraction of this system to migrating waterfowl will be less than that of an aerated lagoon system. Furthermore, moving booms over the trickling filters will tend to discourage resting by migratory waterfowl. The overall effect is likely to be less use by migrating birds. The concerns for possible entrapment in sludge drying lagoons or collision with power lines (Section 4.5) will be slightly diminished. It must be noted, however, that the sources of the threat to migratory birds, i.e., powerlines and sludge drying lagoons, remain. The primary difference between the two alternatives is the presumed degree of attraction offered by differences in surface area of open water.

5.1.2.2 Energy Consumption

Differences in energy consumption during operation of the plant are discussed in detail in Section 4.10. With respect to total present worth, the differences are not significant up to an electricity cost equal to the long range marginal cost (LRMC) of generation ($0.06/kwh). One important consideration, however, is that the burden of operational costs is placed on the Governorate, whereas construction costs are provided at the national level with grant assistance from USAID. No matter what the cost of electricity, the aerated lagoon system requires significantly more energy to operate. For Suez, estimated annual energy consumption for aerated lagoons is three times that of a trickling filter facility. The amount of energy, however, is insignificant in terms of national energy production.

A second important energy consideration is that electricity costs are now significantly subsidized. The government plans to raise the tariff to the LRMC, but the rate of increase to LRMC levels has not been decided. Furthermore, costs of electricity entail primarily a budget issue between the local and national governorate levels. The Canal Cities project includes a tariff study that is underway. The results will be used by the Governorate to establish appropriate user fees and ameliorate the O&M costs. Thus, under present conditions, the difference in energy consumption is not expected to result in a realized significant adverse impact.

5.1.2.3 Operational Reliability

An important factor to consider in comparing the environmental consequences of trickling filter and aerated lagoon technologies is their relative operational reliabilities. Aerated lagoon systems are least susceptible to fluctuations in wastewater load. If for some technical or fiscal reason the aeration system does not operate, the

preferred alternative will continue to provide treatment to the wastewater. The degree of treatment will depend on the length of time that the aeration system is not operational. In the event of equipment failure or power outage for short duration (less than 24 hrs), neither the trickling filter nor aerated lagoon process would suffer dramatically. If the power were out for a longer period of time, the aerated lagoon would produce a better quality effluent than the trickling filter. In the trickling filter system, the biomass would die within a relatively short period after the initial 24 hrs, and it would take time to re-establish the biomass. In the aerated lagoon process, the aerated and facultative lagoons would begin to act as aerobic/anaerobic lagoons after 1-2 weeks.

The rate of BOD reduction in the aerated lagoon process is largely due to the mixing intensity. With high mixing intensity, BOD levels can be reduced faster in a smaller area. Thus, use of a complete mix lagoon significantly reduces construction costs and the amount of land required, but increases operation and maintenance costs. From an operational standpoint, the rate of reduction of BOD would decline if the complete mix lagoon were inoperable, but treatment would be at least as good as primary treatment.

5.1.2.4 Water Quality Impacts

Two relatively minor differences exist between trickling filter and aerated lagoon technologies with respect to water quality impacts. Heavy metal removal rates in the aerated lagoon system are expected to be at least as good as trickling filter systems (Section 4.3), and probably as good as conventional activated sludge techniques. Thus, aerated lagoons offer slightly less risk of adverse impact from heavy metal loading to Suez Bay. Second, the operational reliability of trickling filter systems noted above results in a significant decrease in the degree of confidence in concluding that adverse water quality effects will not occur in Suez Bay (Section 4.3). If a trickling filter system becomes inoperable for longer than approximately 24 hrs, essentially untreated sewage will be discharged to Suez Bay. Although this may be better than present conditions of discharge of raw sewage to the nearshore zone, it would still not be an ecologically desirable situation, and would have a significantly greater adverse impact on Suez Bay than a comparable problem with aerated lagoons.

5.1.3 Conventional Activated Sludge

The conventional activated sludge (CAS) system is comprised of a system of aeration basins and clarifiers. The key to successful performance is the suspension of bacteria in the aeration basins and the conversion of organic wastes into cell tissue.

The greatest environmental differences between the preferred alternative (aerated lagoon treatment) and a CAS treatment system involve:

- migratory bird use of the treatment plant site;
- operational reliability;
- sludge disposal;
- energy consumption; and
- water quality.

5.1.3.1 Impact on Waterfowl and Migrating Birds

A CAS treatment system, like a trickling filter system, will include significantly less open water surface area than would aerated lagoons. Thus, some of the discussion noted above (Section 5.1.2) for trickling filters and their reduced ability to attract migrating birds also applies to a CAS treatment plant. The plant may be less of a magnet for migrating birds than an aerated lagoon system, but the factors that potentially threaten the health of waterfowl remain essentially the same.

5.1.3.2 Operational Reliability

The CAS system is the most susceptible alternative with respect to changes in wastewater load and operational changes. The performance of the plant is sensitive to the type of bacteria growing in the aeration basins and ambient environmental conditions (air and water temperature and wastewater chemistry). It does not take a large perturbation in operational conditions to significantly change the performance of the treatment system, and the system is most demanding of well trained staff and performance monitoring. If the system becomes inoperational, essentially untreated wastewater will be discharged very soon thereafter.

5.1.3.3 Sludge Management

Sludge management also is most complex with the CAS system. In aerated lagoons, stabilization of the sludge occurs passively in the facultative lagoon. Sludge management requires infrequent removal of the sludge from the lagoon bottom, drying in sludge lagoons, and land disposal elsewhere on the site. Sludge generated by the CAS system must be actively stabilized and thickened, requiring additional treatment and increasing the risk of air quality and odor problems.

5.1.3.4 Energy Consumption

Energy requirements for CAS operation are intermediate between aerated lagoon and trickling filter systems, but still significantly less than the aerobic lagoon system. For Suez, a CAS system without primary clarifiers would require about 60% of the energy to operate compared to the proposed aerated lagoon system. This difference would decrease if primary clarifiers were incorporated. The impacts of energy consumption are, therefore, comparable to those described above for trickling filters, but the magnitude of the difference would be less.

5.1.3.5 Water Quality Impacts

Two relatively minor differences exist between CAS and aerated lagoon technologies with respect to water quality impacts. Heavy metal removal rates in the aerated lagoon system are expected to be almost as good as CAS systems (Section 4.3), depending on the amount of algal growth in the polishing ponds. Thus, CAS treatment offers slightly less risk of adverse impact from heavy metal loading to Suez Bay as long as the plant is operating as designed. This advantage, however, is minimized by the proposed use of multiple, subsurface outlets in the polishing lagoons, which minimizes the discharge of algae from the aerated lagoon system.

Second, the decreased operational reliability noted above for the CAS system results in a significant decrease in the degree of confidence that adverse water quality effects will not occur in Suez Bay. If a CAS system becomes inoperable, essentially untreated sewage will be discharged to Suez Bay. Although this may be better than present conditions of discharge of raw sewage to the nearshore zone, it would still not be an ecologically desirable situation, and would have a significantly greater adverse impact on Suez Bay than a comparable problem with aerated lagoons.

5.1.4 Other Alternatives

Other alternative treatment processes have significant technical problems associated with them or are presently innovative, unproven technologies at full scale use. These technologies include treatment via rapid infiltration system or treatment by man-made wetlands.

Rapid infiltration treatment has the significant advantage of eliminating wastewater discharge to the marine environment. Technical reasons, however, have led to the decision not to select this alternative. The primary problems with this alternative were: the lack of sufficient area of available land within economic distance, and problems with high groundwater levels.

Treatment with man-made wetlands may have great potential as a treatment alternative, but it also requires a large tract of land. Wetland treatment, although still not a widely accepted technology, offers advantages in significant reduction of pathogens in the effluent and offering wildlife habitat in otherwise short and rapidly diminishing supply. In addition to large land requirements, however, an added technical drawback is that harvests of wetland vegetation probably must occur on a regular basis, or the system will rapidly lose its ability to polish the effluent. Wetland treatment systems are probably more suitable to small scale wastewater treatment systems.

5.1.5 Sludge Drying

Sludge drying lagoons are proposed for the Suez WWTP site. Odors may result from the sludge drying lagoons. The amount of odor generated will depend on the degree of stabilization achieved in the partially mixed lagoon and the water content of the sludge in the sludge drying lagoon. Prevailing winds will usually blow odors from the site in a south-southeast direction into the bay away from the city center, which should minimize the problem. The design/build contractor will develop proper O&M techniques to minimize odor problems and will train WWTP staff in these procedures.

An alternative approach is to use sludge drying beds. These differ from sludge drying lagoons in that the sludge depth is reduced to allow rapid drying. El-din Hassan (1988) reported that a 0.1 m sludge depth could be dried within 2 to 6 days at Alexandria, Egypt on open drying beds, an equivalent loading rate of 120 $kg/m^2/yr$. This rapid drying time prevented the fly from completing its reproductive cycle. Similar findings have been reported by others.

El-din Hassan (1988) also evaluated the use of solar-heated drying beds. In this process, sludge drying beds are covered and air from a solar collector flows over the drying sludge. This alternative produced drying times for 0.2 m deep beds similar to 0.1 m open drying bed. The solar-heated drying beds were shown to be more economical due to a reduced drying bed area requirement and were preferred for both odor and insect control. The faster temperature rise in the sludge proved lethal for fly larvae.

The main disadvantage of sludge drying beds is that additional labor and land are required. The amount of land made available to the proposed WWTP site by the Suez Governorate constrains the project to using sludge drying lagoons. Furthermore, the capacity of the proposed plant is such that the depth of sludge in the drying lagoons is expected to be similar to that of drying beds. Thus, the advantage of sludge drying beds is probably not significant unless the sludge were to be used as a soil amendment in the future.

5.2 Effluent Disposal Alternatives

5.2.1 Gulf of Suez

Although the Gulf of Suez has more circulation and a higher potential for dilution of sewage effluent (Pirnie-Harris International 1979), it also is the site of several extremely valuable fisheries. These fisheries include benthic species (spiny lobster, crab, octopus, cuttlefish, and shrimp), reef species (grouper, snapper, mullet, and bream), and pelagic species (tuna, mackerel, jacks, sardines, and herring).

Effluent from the wastewater treatment facility poses a minor risk to some of these fisheries occurring near any proposed outfall and increases the health risk to those individuals consuming these species. Pelagic species are highly mobile and are unlikely to remain for long within a wastewater plume. Adverse effects on these species and their respective fisheries are not expected.

The Gulf of Suez is also an area where tourism is increasing at a high rate. Sewage effluent that contains pathogenic bacteria, viruses, and parasites may pose a serious health threat to those contacting the water during recreational activities (i.e., swimming).

Consequently, the Gulf of Suez is not recommended as the preferred alternative due to the potential adverse impacts on the tourism opportunities and benthic fisheries in the vicinity of the outfall. Furthermore, the cost of extending a force main this far is not proportional to the improvement in water quality in Suez Bay that would result.

5.2.2 5-Meter Deep Outfall

As shown in Table 4-2, the 5-meter outfall does not provide the dilution of heavy metals and other pollutants that is produced by the 10-meter outfall. In particular, higher levels of pathogens may be expected along the shoreline during the infrequent event of winds from the east (Section 4.3). There is also concern that this alternative would have a greater risk of adverse impacts on proposed and existing seawater intakes at the fisheries research station and the power plant facilities. Therefore, the 5-meter outfall is not recommended as the preferred alternative.

5.2.3 El Saal Drain

Use of the El Saal Drain as the effluent discharge point for the proposed wastewater treatment facility would continue to produce, albeit to a lesser degree, the adverse impacts in the nearshore zone around the mouth of the drain. These are described more fully in the analysis of the no-action alternative (Chapter 6). These pertain primarily to high levels of fecal coliform bacteria and pathogens in the

nearshore zone, and organic enrichment leading to anoxic conditions in the sediments. Intertidal habitat remains degraded under this alternative, resulting in continued adverse impact on shorebirds.

Unlike the no-action alternative, however, discharge of treated effluent will improve water quality in the nearshore zone. However, the dilution and dispersion will be significantly less than that of either the 5-meter or 10-meter deep outfall. The short-term benefits of improved water quality in the nearshore area will slowly disappear as population and industrialization increases around the city of Suez. Because this alternative offers less benefit to the marine environment, El Saal Drain is not recommended as the preferred alternative.

5.2.4 Effluent Reuse Alternatives

The absence of any sort of reuse as a component of the proposed Suez wastewater treatment system was a prime concern expressed by scoping meeting attendees (Appendix A). NOPWASD and CMC officials noted that nothing in the design of the treatment plant precluded future effluent reuse schemes for agriculture, aquaculture, or municipal irrigation of parks and greenbelts.

Treated wastewater can be a valuable resource for irrigation or aquaculture where supplies of fresh and clean potable water are limited. Reuse contributes to water conservation and has certain economic advantages, such as being available in areas close to where the demand for food is concentrated. In addition, some pollutants are better discharged to the land where they are considered nutrients than directly to the environment. However, such projects can create problems if they are not well planned and managed. A prime consideration is to ensure that the potential for disease transmission is eliminated. This can be achieved by wastewater treatment, crop restriction, control of wastewater application, and exposure control and promotion of hygiene.

Ordinarily, effluent produced from a wastewater treatment plant with little industrial input will most likely be considered adequate for irrigation of cereal crops, industrial crops, fodder crops, pasture, and trees. If other crop irrigation is desired, or if the public in general becomes the exposed group, a fecal coliform guideline of 1000 MPN per 100 ml has been recommended by the WHO (1989). However, effluent reuse at Suez is limited by the high salt content of the wastewater (approximately 5000 mg/l). The Phase II project includes groundwater infiltration studies at Suez, therefore, some reduction in salt content may occur in the future if practical solution can be found. Otherwise, high dilution rates with fresh water would be required before application to agricultural crops, and agricultural reuse probably would not be economically feasible.

Aquaculture is a more plausible alternative for effluent reuse as the salt content is not a factor. Strauss (1985) found little evidence to suggest that significant accumulation of enteric organisms and pathogens in the edible fish tissue occurred when fecal coliform concentrations were maintained less than 1000 fecal coliforms/100 ml. High pathogen concentrations may exist, however, in the digestive tract and intraperitoneal fluid of the fish at lower levels than this (WHO 1989). In the event that a suitable aquaculture site could be found, additional treatment for pathogen removal would be recommended.

5.2.4.1 Agricultural Use

Agricultural reuse of urban wastewater began over 100 years ago with the coming of sewage collection systems. It faded from popularity at the turn of the century when disease problems became more obvious, but is currently undergoing a revival. As competition for water between urban and agricultural users grows, urban wastewater reuse in arid parts of the world is expected to become commonplace. For example, Israel now reuses 35% of its treated sewage water, mainly for agriculture, and targets 80% reuse by the year 2000 (Brown et al. 1990). Modern irrigation technologies such as drip and sprinkle make it easier to apply wastewater safely. The benefits include not only water conservation and reduced pollution of surface water bodies, but also conservation of nutrients.

Wastewater reuse is appealing to an arid, rapidly growing country like Egypt. Cairo's Jebel el Asfar sewage farm dates to 1915 (Shuval et al. 1986a). The Land Master Plan for irrigation development anticipates that up to 40% of Cairo's wastewater will be reused by the year 2000 (Euroconsult-Pacer Consultants 1985). Reuse of Alexandria's wastewater to irrigate a site west of the city has also been considered (French, pers. comm.). Egypt now imports over half its food, and limited water constrains expanding its irrigated area much beyond an additional 25 percent. Inexorably, growing municipal and industrial water use will continue to reduce the amount available for irrigation. By the year 2000, urban usage will reach about 4.8 billion m^3/year, or 9% of Egypt's 55.5 billion m^3/year share of Nile water (World Bank, 1989).

The amount of land irrigable by the wastewater from a 500,000-1,000,000 population city like Suez is not important to the national totals, but can be significant locally. Assuming 60 m^3/ha per day peak summer irrigation requirement for orchard crops and 30 m^3/ha in the winter, by the year 2005 Suez City's wastewater could irrigate nearly 5,000 feddans in the summer; double that in the winter.

Since high oxygen demand does not harm most crops, the preferred alternative's aerated lagoon treatment system will produce a higher quality effluent with respect to BOD than required for agriculture. Disregarding for the moment health considerations and the nuances of crop mineral nutrition, the best effluent for agriculture would have

a high BOD and high suspended solids, retaining as much of the nutrients as possible in organic form (Goldberg 1979).

The present goal of wastewater treatment at Suez is reducing the water quality and public health impacts of raw wastewater discharge into Suez Bay, not water conservation and food production. The potential public health concerns with an agricultural reuse scheme and the high salinity of Suez's effluent explain the chosen preferred alternative. Since the environmental benefits to agricultural reuse could be high if salinity and public health concerns can be resolved, the following sections explore the environmental impacts of this disposal option in more detail.

5.2.4.2 Health Considerations

The main public health concern is the risk to farmers and food consumers from wastewater irrigation. To summarize from Shuval et al. (1986a): 1) infective doses of pathogens remain in effluent after conventional secondary treatment; 2) helminths (*Ascaris, Trichuris,* and hookworm) are particularly resistant, for example, *Ascaris* eggs can remain infective even after 1 year in the soil; 3) the most likely mode of disease transmission is irrigation of vegetables consumed raw with poorly treated wastewater; and 4) the main livestock-related problem is spread of beef and pork tapeworms (*Taenia saginata* and *Taenia solium).*

Reducing helminths and protozoa, whose eggs and cysts are highly persistent and infective doses are low, is more critical than reducing levels of bacteria and viruses, which tend to have the opposite traits. The simplest treatment method is settling out eggs and cysts in a combination of anaerobic and aerobic ponds. According to Shuval et al. (1986a):

> "A minimum of 1-2 days' detention in anaerobic ponds followed by 7 days in facultative aerobic ponds appears to be the minimum desirable treatment of sewage before agricultural use to achieve effective control of helminths or protozoans that might infect agricultural workers or crops, animals, or fish exposed to sewage" (p. 167).

The proposed aerated lagoon system with its 11-day total, 5-day quiescent, retention time should remove most, but not all, protozoa and helminths. Full removal would likely require either additional maturation ponds to increase the quiescent period by 5-10 days, or filtration. In the years before the plant reaches maximum capacity, its operators may have the option of lengthening the retention time to increase pathogen removal. Should an agricultural reuse system be adopted in the future, health officials should determine whether full removal of helminths and protozoa is necessary, and maintain a monitoring program.

The World Health Organization (1973) recommends that reused effluent not contain more than 100 coliforms/100 ml in 80% of samples. In Egypt much of Nile and irrigation canal water would not pass this recommended guideline. Acceptable coliform standards may need to reflect the irrigation method, crops grown, and farm organization. The range of possibilities include small farmers in frequent contact with the effluent, and a large-scale mechanized operation using technologies that minimize the contact.

WHO (1989) has prepared general guidelines for prudent levels of treatment of effluent applied to particular crops (Table 5-1). These guidelines are appropriate to effluent reuse by small farmers. Most general purpose guidelines such as those in Table 5-1 do not consider irrigation method. With modern irrigation techniques, effluent contact with crops and farmers can be reduced. Using drip irrigation, minimally treated water can be used safely to irrigate fruits and certain vegetables. Fodder crops can be grown using undisinfected primary-treated effluent under center pivot sprinkler systems without ill effects to farmers and meat and dairy product consumers, if strict controls and pathogen monitoring are maintained.

Egypt's Law 93 of 1962 (modified by Decree No. 9/1989) governs the reuse of urban wastewater for agriculture. Law 93 was meant to fit Egyptian circumstances and, thus, does not parallel the WHO (1989) recommendations noted above. Law 93 provisions include:

- The disposal site should be at least 3 km from urban or village boundaries.
- The sewage should receive a minimum of primary treatment.
- Cultivation of vegetables, fruits or other crops eaten raw should be prohibited, and the land should not be used for the rearing of animals or dairy cattle.
- Excessive percolation to underground aquifers should be prevented.

Law 93 appears to allow only non-food industrial crops, heat-processed foods (for example, sugar beet and sugar cane, and wheat), and trees for windbreaks and timber. Strictly speaking, much of what the Jebel el Asfar sewage farm now grows is not consistent with Law 93. In the mid-1980s, about 2500 feddans were cropped at Jebel el Asfar using a mixture of primary- and secondary-treated water. Crops included: citrus, 1715 feddans; eucalyptus and trees, 570 feddans; maize and beans, 190 feddans; vegetables, 25 feddans (Euroconsult-Pacer Consultants 1985).

Table 5-1. Recommended microbiological quality guidelines for wastewater use in agriculture.

Category	Reuse conditions	Exposed group	Intestinal nematodes (arithmetic mean no. of eggs per litre)	Fecal coliforms (geometric mean no. per 100 ml)	Wastewater treatment expected to achieved the required microbiological quality
A	Irrigation of crops likely to be eaten uncooked, sports fields, public parks[a]	Workers, consumers, public	≤1	≤1000[a]	A series of stabilization ponds designed to achieve the microbiological quality indicated, or equivalent treatment
B	Irrigation of cereal crops, industrial crops, fodder crops, pasture and trees[b]	Workers	≤1	No standard recommended	Retention in stabilization ponds for 8-10 days or equivalent helminth and fecal coliform removal
C	Localized irrigation of crops in category B if exposure of workers and the public does not occur	None	Not applicable	Not applicable	Pretreatment as required by the irrigation technology, but not less than primary sedimentation

Source: WHO 1989.

a: A more stringent guideline (<200 fecal coliforms per 100 ml) is appropriate for public lawns, such as hotel lawns, with which the public may come into direct contact.

b: In the case of fruit trees, irrigation should cease two weeks before fruit is picked, and no fruit should be picked off the ground. Sprinkler irrigation should not be used.

5.2.4.3 Wastewater Chemical Composition

Egypt's Law 93 stipulates some specific water quality standards for urban wastewater used for agriculture. Its provisions distinguish between sandy and clay soils.

- For sandy soils:
  - residual materials in 1 hr less than 1 cm^3/liter;
  - oils, greases, and resins less than 10 ppm;
  - sulfides (based on S) less than 1 ppm.
- For clay soils:
  - pH between 6 and 9;
  - BOD not exceeding 80 ppm;
  - COD not exceeding 50 ppm;
  - SS not exceeding 80 ppm;
  - Sulphides not exceeding 0.1 ppm;
  - Oils, grease, and resins not exceeding 5 ppm;
  - Dissolved solids not exceeding 200 ppm;
  - Cyanide not exceeding 0.1 ppm.

The two most important chemical properties of the effluent that affect suitability for reuse are: 1) the level of total dissolved solids, and 2) concentrations of heavy metals and other trace elements. Recent sampling finds concentrations of 5,300 ppm TDS in the Suez wastewater influent. This level is much too high for crop cultivation except by skilled managers using the most sophisticated techniques. The high concentration probably arises from infiltration of saline groundwater into the collection system.

Egypt lacks specific standards for trace element and heavy metal concentrations in irrigation and waste water. The main concern is their slow accumulation in the soil profile and later toxic effects on plants and plant consumers. Recommendations for maximum concentrations in irrigation water are based on assumptions of a certain rate

of irrigation over a long period. The often cited U.S. recommendations assume application rates of 2 cm/week for 20 years (EPA 1980). Table 5-2 shows the EPA's recommended maximum trace element and heavy metal concentrations adjusted to 3 cm/week, a more likely irrigation rate for the Suez area, and available data on concentrations in Suez's influent.

The sparse data in Table 5-2 suggest that cadmium may be too high and copper may be close to recommended maximum concentration. At present, most of Suez's industrial wastewater is not discharged into the collection system. If in the future industrial wastewater is collected, heavy metal and trace element concentrations may be high even after treatment. Regular monitoring of effluent chemistry and regulation of industrial discharges into the waste stream should accompany agricultural reuse.

5.2.4.4 Environmental Effects

Reusing the effluent for agriculture would create a new balance sheet of beneficial and adverse environmental effects, the precise tallying of which would require a separate assessment.

The most beneficial effect would be significant reduction of effluent discharge into Suez Bay. Fluctuating water requirements for irrigation mean that discharge would not be eliminated completely, but a well conceived reuse scheme could reduce it significantly. Another direct effect would be increasing the amount of greenery in the Suez environs. If an area to the northwest of the city were reclaimed, for example, the effects of wind and dust from that direction would be reduced. The existing agriculture to the north of the city in combination with new areas to the northwest along the Cairo-Suez road could act as a greenbelt to reduce urban sprawl in those directions and induce more compact development.

The adverse effects require detailed study to fully identify, but they are those generally associated with new irrigated lands development. Of most concern are adverse health impacts to farmers and food consumers. These will depend on a combination of factors: pathogen levels in the effluent, crops grown, irrigation method, and farming system.

Irrigating 5,000 feddans close to Suez could affect groundwater level and quality in the city. Proper drainage would be necessary to prevent levels from rising even higher than they are at present. Leaching to the groundwater of nutrients, nitrogen in particular, can be a problem with effluent reuse for irrigation. This might not be critical at Suez where the groundwater is highly saline and not used for drinking water.

Various other adverse impacts might arise as a result of introducing agriculture where it was not previously occurring. These would include: insects, odors, agricultural chemical spread, and the propagation of water-borne diseases with the irrigation water.

Table 5-2. Recommended Maximum Concentration of Trace Element and Heavy Metal Ions in Irrigation Water, and Concentrations in Suez City Wastewater Influent. (ppm, 3 cm/week)

	Continual Use All Soils	Suez City Wastewater Influent	Predicted Effluent[a]
Aluminum	3.333	ND	-
Arsenic	0.067	ND	-
Boron	0.500	ND	-
Cadmium	0.007	0.05	0.008
Chromium	0.067	ND	-
Cobalt	0.333	ND	-
Copper	0.133	0.5	0.125
Fluoride	0.667	ND	-
Iron	3.333	0.3	(b)
Lead	3.333	0.2	0.046
Manganese	0.133	ND	-
Molybdenum	0.067	ND	-
Nickel	0.133	0.09	0.081
Selenium	0.013	ND	-
Zinc	1.333	0.4	0.108

a: From Table 4-2
b: Removal efficiency unknown
ND: No data
Source: CMC; EPA 1980.

Schistosomiasis, for example, could occur even if the water were completely free of wastewater pathogens.

Soil salinization is considered a major adverse environmental impact of irrigation. The candidate desert soils at Suez are highly saline in their present state and require leaching before cultivation. Irrigation of such soils with what likely would be moderately saline water would require careful management of the salt balance.

Other factors that should be considered in effluent reuse for agriculture are briefly summarized in Appendix D.

5.3 Sludge Disposal Alternatives

Sludge disposal alternatives have not been given primary attention, as attention has focused on obtaining suitable land that will allow construction of the treatment plant facilities and disposal of sludge on site. Alternatives to disposal of the sludge on the site include use by farmers for land reclamation and soil amendment, and composting with municipal solid waste.

Use of sludge as a soil amendment appears highly desirable in Egypt because of a need for more arable land. Primary concerns, however, are implications for human health as a result of pathogens and heavy metals in the sludge. Issues associated with pathogens are discussed in greater detail in Section 4.9. Heavy metals may pose a risk not only to human health but also to plant survival if levels in the soil rise over repeated use. Thus, significant adverse impacts may arise from use of sludge as a soil amendment.

Composting with municipal solid waste may offer important advantages, but impacts cannot be adequately evaluated without description of a proposed plan. Such a plan does not exist at this time.

5.4 Disinfection Alternatives

Disinfection is the most frequently used treatment process to achieve satisfactory fecal coliform levels in the receiving water. It is also quite effective in inactivating most viruses, although viruses tend to be more resistant than bacteria (Payment 1989).

Effluent disinfection is not usually practiced when marine outfalls are used. Most of the pathogens can survive for only short periods in the marine environment, and the planned diffuser will increase the dilution with the receiving waters. Routes of exposure are limited to recreational use of the ocean and consumption of contaminated seafood. The incidence of disease at locations with long outfalls is typically low due to: a) exposure to less than minimal infective doses in the nearshore zone; and b) host

immunity (Gunnerson 1988). The incidence of disease reaches unacceptable levels if wastewater is discharged on the beach or is able to rapidly reach the shore in high use recreational areas. Incidence of disease also rises if recreational users are from areas with lower rates of infection or immunity from waste-related pathogens.

At the present time, it appears that fecal coliform counts near shore will meet Law 48 standards with discharge to 10-m deep water. Due to the minimal amount of recreational activity in Suez Bay and the lack of fishing and shellfishing activity, effluent disinfection cannot be justified on health grounds for this project. This issue will require reevaluation, however, if subsequent analyses in final design indicate that: a) recreational use of Suez Bay will increase significantly; or b) treatment plant performance or outfall configuration may result in higher levels of fecal coliform bacteria on shore than deemed acceptable. In this case, additional treatment processes which would upgrade the quality of the effluent may be required, and are presented here. Such processes also may be necessary in the future if reuse of the effluent is considered feasible.

5.4.1 Chlorination

Chlorination is one of the most commonly used disinfectant methods in present-day wastewater treatment facilities. The process of adding either chlorine (Cl_2), calcium hypochlorite [$Ca(OCl)_2$], or sodium hypochlorite [Na(OCl)] is the next to the last step in the wastewater treatment process. The primary function of chlorination is to eliminate those bacteria and viruses that are considered pathogenic to man (Metcalf and Eddy 1979). Disinfection is inefficient, however, for eliminating protozoal cysts and completely ineffective against helminth eggs (Shuval et al. 1986a), which is a major consideration in this project.

It is estimated that 1300 kg/day of chlorine would be needed to disinfect the Suez effluent at a dosage of 10 mg/l (Dong, pers. comm.). A total contact time of 30 minutes would be required prior to discharge.

Although a powerful disinfectant, chlorine is highly toxic to marine organisms. Phytoplankton production (photosynthesis) has been determined to be greatly inhibited upon exposure to chlorine levels as low as 0.01 mg/l (Finlayson and Hinkelman 1977). The adverse effects of chlorine in heated water upon zooplankton populations has been well documented (Icanberry 1973; Heinle 1969; Gentile et al. 1976). Oyster and clam larvae are adversely affected at chlorine concentration of 0.005 mg/l and 0.001 mg/l respectively (Roberts et al. 1975). Zooplankton mortalities ranged from 65.4 to 100% at chlorine concentrations of 0.4 mg/l with associated water temperatures of 28° to 30° C. Typical chlorine dosages for disinfection range from 1.0 mg/l to 25.0 mg/l (Metcalf and Eddy 1979). Water temperatures at the wastewater treatment facility in Suez commonly range between 25° and 30° C. Thus, chlorination of wastes may have an adverse effect on planktonic organisms in the zone of initial dilution.

Marine fish are extremely sensitive to chlorine. Colwell (1981) stated that chlorination should be eliminated at wastewater treatment facilities around Chesapeake Bay (United States) due to its adverse effect on larval fish. Complete mortality occurred when larval flounder (*Paralichthys* sp.) and striped mullet (*Mugil cephalus)* were exposed to chlorine concentrations of 0.3 mg/l and 0.5 mg/l, respectively, for a 10 minute period (Hoss et al. 1974).

In addition, there are major difficulties in Egypt to implement and maintain the types of chlorination facilities (chlorine gas) that are normally provided in other countries. Chlorine gas is expensive, and the gas and the bottles and tanks used to transport it are in short supply. Thus, it cannot be assumed that chlorination can occur on a sustained basis. Generation of chlorine on site using hypochlorite salts is possible, but the energy costs are likely to be significant.

In conclusion, it appears that chlorination would be expensive, unreliable, and lead to adverse environmental effects unless dechlorination were also to occur. Thus, chlorination is not recommended.

5.4.2 Dechlorination

Dechlorination is the procedure by which total combined chlorine residuals are removed after chlorination. This process is usually the last step in the wastewater treatment process. The reason for dechlorination is that certain organic constituents in wastewater may react with chlorine to form toxic compounds (residuals) that can have long-term effects on the waters into which they are discharged (Esvelt et al. 1971; Metcalf and Eddy 1979). Furthermore, chlorine, as noted above, can be highly toxic to marine species. To minimize these effects on the marine environment, dechlorination procedures should be implemented (Stone et al. 1973) if it is eventually decided to provide chlorination of the Suez effluent.

5.4.3 Other Disinfection Techniques

Ozonation generally requires pilot plant testing to determine necessary dosage. Ozone generators require dry air, oxygen-enriched air, or pure oxygen for proper operation. Air-fed ozone generators require clean air as well as high maintenance frequency. With sand storms and oil refineries in the Suez area, air-fed ozone generators will require constant monitoring and maintenance. Highly specialized maintenance personnel will be needed, and they are likely to be difficult to hire and keep on staff. Maintenance costs are also likely to be high.

Assuming Suez wastewater would require about 650 kg/day of ozone, a minimum of 13,000 kwh/d would be required to operate the air-compressors, generators, and

cooling tower pumps (Dong, pers. comm.). This represents a significant additional daily energy consumption. Between maintenance and operational costs, ozonation would be as much as three to four times more than chlorination costs. Finally, capital cost to install a complete ozone generation facility is approximately four to six times the cost of installing a complete chlorination system.

Ultraviolet radiation is effective for disinfecting clean effluent (Severin 1980), although power costs and bulb replacement may be a problem. The primary key to ultraviolet radiation is that the effluent have low total suspended solids, i.e 30 mg/l or less. The proposed treatment process cannot be guaranteed to produce this quality of effluent, although it may be possible under certain operational conditions. Ultraviolet radiation also requires frequent monitoring and maintenance.

High coliform removals (99 percent) have also been achieved without disinfection by use of peat filter fields; however, effluent application rates are very low (Brooks et al., 1984; Nichols and Boelter, 1982).

Preliminary analysis suggests that these alternate forms of disinfection are not well suited to conditions in Egypt.

CHAPTER 6

6.0 ENVIRONMENTAL EFFECTS OF THE NO-ACTION ALTERNATIVE

USAID is committed to constructing a wastewater treatment facility for Suez; therefore, the no-action alternative is not likely to be selected. If the no-action alternative were to be selected, approximately 60,000 m^3/d of wastewater would undergo primary sedimentation and anaerobic lagoon treatment at NOPWASD facilities now nearing completion at the existing WWTP site. This treated effluent would be discharged to El Saal Drain. The remaining flow (approximately 70,000 m^3/d in year 2005) would continue to flow untreated to El Saal Drain. At the present time, the majority of the existing flow of 67,200 m^3/d is discharged untreated to El Saal Drain.

Under the no-action alternative, wastewater discharge to Suez Bay from El Saal Drain in the year 2005 would approximately double existing levels. The flow of untreated wastewater would remain approximately the same. The additional flow, however, would entail better than primary but less than secondary treatment. The environmental consequences of this alternative are briefly described in the remainder of this section.

6.1 Water Quality

Shore and nearshore pollution of the bay is currently significant within a few hundred meters of the El Saal Drain outlet to Suez Bay, which is the discharge point for the existing Suez wastewater treatment plant's untreated domestic wastewater. Based on both visual observations during the field sampling program in November-December 1989 and analysis of water column profiles, wastewater from the El Saal Drain now spreads out over the nearshore surface of the bay in a buoyant, freshwater lens. This layer varies in thickness, but was never greater than 1 m thick and was often only a few centimeters thick in November-December 1989 (Appendix B). The maximum offshore (i.e., southward) extent of this surface layer that was observed during the study was approximately 1.5-2 km off the mouth of the El Saal Drain (Dames & Moore 1990).

Field studies conducted in July and November-December 1989 (Dames & Moore 1990) found that water quality conditions in Suez Bay had not significantly changed from conditions observed a decade earlier (Pirnie-Harris International 1979), with one important exception. Fecal coliform concentrations in July 1989 were higher than observed in 1979, generally in the range of 1000 organisms/100 ml. The reason for the difference is not clear. The methods used for determining the counts appear similar, and samples were filtered on the survey vessel and immediately incubated for both studies. Some increase in coliform numbers was to be expected, as the 1989 sampling

was concentrated more around the El Saal Drain outlet; however, counts in the middle of the bay also differed significantly between the 1979 and July 1989 surveys. These data suggest that contamination of surface water in Suez Bay by human waste has increased in the past 10 years. Much of this impact is probably due to the discharge of untreated wastewater from El Saal Drain and subsequent wind-driven movement of the less-saline wastewater on the surface of Suez Bay.

There is still very poor definition of other discharge points and pollutant loadings into the bay, for example, discharges from the oil refinery, fertilizer factory, and other drains. An oil sheen from onshore sources covers a large area near the El Saal Drain outlet. Other oil pollution in the bay is significant and is visually apparent. Although water quality in Suez Bay shows signs of oil pollution and pollution around the El Saal Drain from wastewater discharge, all available indications are that the bay is satisfactorily coping with the existing situation with respect to nutrients and oxygen levels. In general, despite nearly 10 years of discharges of untreated wastewater into Suez Bay from the existing Suez wastewater treatment plant (WWTP), as well as pollution from other sources, water quality conditions as monitored in July 1989 with respect to nutrients and dissolved oxygen are not markedly different from conditions measured in 1979. The only significant difference appears to be the increased degree of contamination by fecal coliform bacteria in the surface water throughout the bay. This implies that the risk of public health problems has also increased over time.

Analysis of water quality samples from El Saal Drain taken in November-December 1989 approximately 500 m upstream of the outlet to Suez Bay indicated a highly variable fecal coliform count with a mean of 20,837 MPN/100 ml (Dames & Moore 1990). These high values indicate that nearby residents are exposed to not only nuisance odors associated with untreated sewage but also potential health risks. Approximately 500 m offshore of the outlet of El Saal Drain, counts were highly variable with a mean of 2,355 MPN/100 ml. A doubling of flow by the year 2005 would also significantly increase the quantity of fecal coliform bacteria discharged to the nearshore zone of Suez Bay. The increase, however, would not be doubled, because the increase in flow would entail a significant fraction of effluent that received primary sedimentation and anaerobic lagoon treatment.

The increase in fecal coliform bacteria in Suez Bay with the no-action alternative is expected to be large and have a significant adverse effect on water quality and public health in the nearshore zone. Increase in BOD and nutrient loading to the nearshore zone is also expected to be large, with the most adverse effect within a few hundred meters of the El Saal Drain outlet.

6.2 Marine Resources

Nutrient loading from human waste may have only minor effects on the marine resources of Suez Bay. Increased loading of BOD may begin to adversely affect

oxygen levels in the nearshore zone water column, particularly in the nearshore zone, if no action is taken. When coupled with other pollutant sources such as power generating stations, fertilizer plants, refineries, petroleum processing facilities, marinas, shipyards, and ships at anchor, the resultant effect on the marine environment can be dramatic.

Under the no-action alternative, nutrient loading will be localized to the nearshore area around El Saal Drain. Phytoplankton in the bay appear not to be nutrient limited (especially in view of the fact that raw sewage is currently discharged to the bay with little apparent effect on chlorophyll a) but limited by light and, in some instances, turbidity. Pollutants contributed by other sources mentioned in the preceding paragraph serve as additional inhibitors of phytoplankton productivity. Thus, the no-action alternative is not expected to have a significant adverse effect on phytoplankton.

With phytoplankton (primary) production limited by light, zooplankton productivity is lowered. Compounding this fact, the presence of industrial waste discharges may provide additional deleterious effects on zooplankton populations. Suspected concentrations of antifouling agents (e.g., TBTs) from the numerous ships in the bay and in cooling water discharges are also believed to depress zooplankton populations. Wastewater discharge under the no-action alternative is not expected to have a significant adverse effect on zooplankton production.

Sediments on the sea-floor form a sink for a number of pollutants including organic wastes, oil (either from refineries or spills), and heavy metals (Dicks 1987). Severe benthic faunal depletion has been discovered around sewage and refinery effluents (Dicks and Hartley 1982; Read et al. 1983). It should be noted that at Stations 1, 2, and 3 (neighboring the mouth of El Saal Drain) in the Dames & Moore (1990) survey, hydrogen sulfide (H_2S) was found to be present in the sediments. This condition is typical of bottom sediments where organic loading has exceeded assimilative capacity and produced anoxic conditions in the sediment. Behairy and Saad (1984) found similar conditions near untreated sewage discharges in two localities in the southern reaches of the Red Sea. Amoebic cysts, which are indicative of sewage contamination, were found in the sediments of Suez Bay at stations near the mouth the El Saal Drain outlet. The distribution of these cysts, which may be potentially pathogenic (Sawyer and Lewis, 1989), was correlated to sewage outfall and currents in the bay. Finally, bivalves have been shown to retain pathogenic bacteria associated with sewage outfalls. This retention is due to their high filtration rates (Diab 1989).

These data suggest that discharge of untreated sewage via El Saal Drain will continue to have an adverse impact on benthos in the nearshore zone around the outlet. As wastewater flows increase, this adverse effect on benthos is expected to expand in area. This impact, however, is not expected to be significant because: a) the area is localized to the nearshore zone; b) benthic diversity appears to be low in Suez Bay; and c) benthic biota do not appear to support a fishery in Suez Bay or support a large fish community. Nevertheless, this impact is unnecessary and can be remedied

with improvement in treatment and discharge of wastes to an area with better dilution and dispersion and, therefore, greater ability to assimilate the waste. Added to the public health risks associated with the no-action alternative, these impacts are environmentally unacceptable.

Sewage and industrial wastes have also been shown to have negative impacts on egg, larval, and juvenile stages of fish populations. Adult fish have been shown to harbor human pathogenic bacteria and viruses after exposure to contaminated water or food sources (Diab 1989). Wastewater discharge under the no-action alternative is expected to have a continued and potentially increasing adverse impact on those fish species inhabiting the nearshore area around the El Saal Drain. Transient species could also be negatively affected by feeding on diseased or infected prey. These adverse impacts will increase as the flow of wastewater increases. Over time, declines in levels of dissolved oxygen may become larger and be noticeable over a larger area.

A variety of toxic pollutants such as heavy metals and pesticides are introduced to Suez Bay from a variety of sources. These sources include: a) the wastewater treatment facility; b) industrial discharge; c) agricultural runoff; and d) shipping traffic. Because fish are mobile, bioaccumulation of these pollutants cannot be directly attributable to any one individual pollutant source. Bioaccumulation, as quantified by the tissue burden of pollutants, is the result of a fish's history of exposure to contaminants from multiple sources of toxicants within Suez Bay. There are no data on bioaccumulation for Suez Bay. At the present time, waste discharge to Suez Bay is untreated. As a result, metals in the sewage are not reduced by treatment and are therefore available at higher quantities for bioaccumulation by organisms in the wastewater plume. The no-action alternative is expected to produce persistent adverse effects, especially around the El Saal Drain, because of continuing effluent discharge containing heavy metals. Metal loading to the nearshore area will not be significantly reduced in the no-action alternative because 50 percent of the flow in the year 2005 will be untreated.

In summary, under the no-action alternative there appears to be few significant adverse impacts to the marine resources of Suez Bay. However, localized adverse impacts to the nearshore zone around the outlet of El Saal Drain are already in evidence. These impacts will most likely continue and incrementally increase in the future with increased discharge under this alternative. These adverse impacts, however, are unnecessary and can be remedied with action; they are, therefore, unacceptable.

6.3 Terrestrial Resources

Selection of the no-action alternative will mean that the proposed wastewater treatment plant will not be constructed at the proposed site on the west side of Suez

Bay. Loss of habitat of generally low value and use by wildlife will, therefore, not be incurred. The existing, small degree of use of the site by reptiles and birds will continue. These include breeding by desert larks and crested larks and possible foraging by palm doves and collard doves. Brown-necked ravens, white-crowned black wheatears, and birds of prey may also continue to occasionally use the site. The benefits of this continued use, however, are small; the proposed treatment plant site is not a significant wildlife habitat (Section 3.8).

Selection of the no-action alternative will eliminate the attraction of open water lagoons at the proposed treatment plant site to migrating bird species. Selection of the no-action alternative means that sewage treatment via anaerobic lagoon systems will continue at the existing site, which is further removed from the primary migratory bird flight path and, therefore, represents a slightly less attractive lure to migrating birds than would the new treatment plant at the proposed site.

On the other hand, as the city of Suez continues to grow in the direction of the existing wastewater treatment plant, human disturbance of birds using the existing plant for resting and foraging will likely increase. In particular, opportunities for illegal trapping and hunting of migrating birds will also increase.

Selection of the no-action alternative means that either a large fraction of untreated waste will continue to flow via El Saal Drain to Suez Bay, or major expansion is required of the existing facilities. If the former were to occur, untreated sewage will continue to pollute large areas of intertidal habitat, which is a major foraging and resting area for waterbirds migrating through the Suez area. Waders in particular use these mudflats (Section 3.5.6) for foraging as well as resting. The mudflats of Suez Bay are probably among the most critical habitats of that type in the whole northern part of the Red Sea for waders. Continued pollution of this critical resource by raw sewage is potentially a significant adverse effect on the health of migrating waders.

If major expansion of the existing treatment plant were to occur, an additional treatment plant site is likely needed because the existing plant occupies most of the space available to it. The effects on terrestrial resources cannot be assessed without additional information on the proposed site if it were different than the one being considered here. Selection of the proposed WWTP site was made in consultation with the Suez Governorate, and one would expect the same site would be selected if a plant were built without USAID partial funding.

In summary, balancing the long-term advantages and disadvantages of the no-action alternative suggests that there would be no significant advantage to terrestrial resources and migrating birds under the no-action alternative. If the no-action alternative were selected, significant adverse effects of one type (e.g., contamination of mudflat foraging grounds) or another (e.g., loss of habitat due to construction at the

existing site if the project goes on with other funding sources) are likely to occur anyway.

6.4 Geology and Soils

Selection of the no-action alternative means that geology, soils, shoreline, and bay sediments at the proposed treatment plant site and in sewer line and outfall corridors will not be disturbed. Eventually, however, the proposed treatment plant site is likely to be developed for some alternative industrial use. These construction-related impacts, therefore, are probably only deferred by selection of the no-action alternative.

Ground surface contamination presently exists at locations along the proposed sewer line route between the existing and proposed treatment plants. Contaminants include large pools of spilled crude oil, wastewater in open ditches and depressions, and refuse. Therefore, an adverse environmental situation already exists irrespective of the alternative selected.

The eastern part of the proposed wastewater treatment plant site is presently used for the dumping of solid and liquid wastes. Mobile pollutants from these wastes can infiltrate into the soil. The corrosion, breakage, and subsequent leakage of underground pipelines, which cross or are adjacent to the site, could occur. In addition, the discharges from existing nearby industrial facilities or future developments will have an environmental impact on the geology, soils, shoreline, and bay sediments in the vicinity of the plant site, sewer line, and outfall corridors. Therefore, adverse environmental impact may continue irrespective of the selection of the no-action alternative.

6.5 Groundwater

Contamination of groundwater at the proposed wastewater treatment plant has already been noted (Section 3.7). Surface contamination of soils along the proposed sewer-line corridor between the two treatment plants are potential sources of groundwater contamination. Thus, the no-action alternative offers no advantage to groundwater protection.

6.6 Land Use and Services

6.6.1 General

If the USAID-funded treatment plant is not built, Suez will continue using the existing facility, which is currently being rehabilitated to handle 60,000 m^3/day in an

anaerobic lagoon treatment system. If the Egyptian Government installs no new wastewater treatment capacity until after 2005, it would mean a brief period of improved water quality and shoreline conditions within 1 km of the El Saal Drain discharge point, consistent with the City's intention to clean up the bay shore. For a brief time, fecal coliform counts would be lower in the nearshore zone and sewage would be less obviously visible on the water surface. The impact of odors and other nuisances from the drain on adjacent housing would lessen. But by 2005 the wastewater flow to the plant would be double the present levels, and the amount of raw wastewater going to the bay would be about the same as in 1990. More people would be affected by nuisance conditions and by increased public health risk than are now because the number of people living along the drain and around the existing WWTP would be larger.

The ultimate no-action alternative will not likely transpire. The city would probably continue expanding its existing plant, but, as with the current expansion, not in step with increased flows. Wastewater will receive at best partial treatment, better in some years than others.

6.6.2 Present and Proposed Wastewater Treatment Plant Sites

There are two problems with the current approach to handling wastewater at Suez. First, land use plans call for developing the area around the existing plant for housing. The area around the existing WWTP is well suited for residential-commercial use because it is near both the urban core service area and industrial zone workplaces. The Feisal City housing project is approximately 1 km to the northeast, and a new park is being built approximately 1 km to the north. Construction of new housing in the area will constrain treatment plant expansion. Alternatively, expanding the existing WWTP will use land better suited for housing, and increase the nuisance from flies, odors, and noise to existing residents. In either case, adequate buffers to protect residents from nuisance odors and flies will be eliminated. Thus, the no-action alternative will significantly constrain residential land use plans around the existing WWTP site.

The second problem is associated with discharging effluent into the El Saal Drain and its flow directly into the bay. Untreated effluent will pose a health hazard to swimmers and beach users for several hundred meters around the discharge point. The El Saal Drain would continue to be a nuisance and health threat to those living along it, even if the effluent's quality improves with improvements near completion at the existing WWTP site. These health risks represent a significant adverse effect on the quality of life of nearby residents.

The site for the proposed new treatment plant is an area designated for industrial expansion. A site just to the south has been designated for use as a graphite factory. It is likely that the land at the proposed WWTP site eventually will be used

for industrial purposes if it is not used for the proposed WWTP. Workers at the graphite factory would not be exposed to wastewater odor problems. This could be considered a benefit, unless an alternative industrial use is made that generates different (or worse) odors or nuisance problems. At the present time, construction debris is occasionally dumped on the site, and this activity is likely to continue. Thus, selection of the no-action alternative will not necessarily have a beneficial effect on nearby land uses.

One positive benefit that will occur is that quarry operations now occurring on the western end of the site would be able to continue. Current plans call for relocation of the quarry operations and use of the quarry for sludge disposal.

6.6.3 Demography

In a developing country such as Egypt, expanding wastewater treatment capacity does not induce new residential construction or attract new industry to a city. By themselves, environmental improvements incurred by building the proposed treatment plant will only modestly attract more people to live in Suez, or lure more tourists. Nor will failure to build the WWTP plant necessarily keep the city from growing. Under the no-action alternative, more Suez residents would suffer from ailments resulting from exposure to untreated wastewater, but the adverse health effects would not significantly change the demographic future. Failing to build the proposed treatment plant will have little impact on Suez's population growth. Failure to build the WWTP and the resulting continued pollution of Suez Bay will be one more factor to add to the poor air quality and oiled beaches that discourage tourism.

6.6.4 Water Use and Wastewater Flow

It is difficult to predict what Suez's potable water and wastewater departments would do differently without the USAID project, of which the proposed treatment plant is only one element. Without the project's institution building components, management of Suez's wastewater collection and treatment system will improve more slowly. This will have several consequences: e.g., slower expansion of the service area, less effective tariff collection, poorer management of the treatment plants, and less capability to manage potable water supply and wastewater.

6.7 Public Health

New housing projects are under construction, an improved water supply is available, and improved sewage collection and pumping systems have been installed at Suez. While these public works have improved public health, the collected wastewater flow receives virtually no treatment. About 50% of the wastewater flow passes through

a series of old primary settling tanks. The remaining flow bypasses these tanks and joins the primary effluent discharge which flows into the El Saal Drain and runs into Suez Bay next to the oil company residential area and other homes along the beach.

The discharge of this flow into the bay impacts the nearshore environment significantly. There are strong sulfide odors in this area and black sediments in the nearshore zone resulting from anaerobic bottom conditions. There is also considerable oil pollution from the nearby oil refinery and ships moored in the bay.

While existing conditions are not aesthetically pleasing and do not encourage swimming, local health officials have reported that some swimming does occur and that incidences of skin and ear infections have resulted from recreational water contact (Dames & Moore 1990). This is not surprising. Field data suggest fecal coliform counts in lower El Saal Drain may average two orders of magnitude over levels adopted as guidelines in the United States for recreational water use. Thus, individuals who use the beaches in Suez Bay for swimming are exposed to unacceptable levels of viruses and pathogens found in untreated sewage.

There is no fishing or shellfishing activity within the bay, primarily due to security reasons, and there have been no reports of sickness due to consumption of seafood collected from this area.

Sludge from the existing primary tanks is removed and dried on drying beds. There is a fly problem at the existing plant site. Mosquitos were not observed during the field visits, and few locations that would be suitable for mosquito breeding were identified. Stray dogs also inhabit the plant site but their potential as disease vectors is unknown.

In the near future, the new NOPWASD treatment plant will be put into operation. This plant, consisting of anaerobic and facultative lagoons, will produce a major improvement in the quality of the effluent discharged to the bay and minimize most of the nuisance problems associated with the existing sludge handling and disposal processes. This improvement, however, will be only temporary. Furthermore, to meet Law 48 standards for BOD, the plant could only treat 14,000 m^3/day. By the year 2005, wastewater flows will double the capacity of the new NOPWASD plant. Discharge of untreated wastes to El Saal Drain in the year 2005 will occur at levels essentially equal to current levels. Adverse effects on public health will continue as long as individuals come into contact with polluted water in the nearshore zone. At the present time, these impacts are not significant because levels of contact and recreation use are low. Over time, the impacts are likely to become more noticeable as larger flows of sewage occur and the city's population increases. If planned tourism and water recreation opportunities are developed, the impact will become greater. Given that these problems can be significantly reduced by the proposed action, the present condition and future conditions under no-action are unacceptable.

6.8 Energy

Under the proposed action, energy will be consumed to construct, operate, and maintain the plant. The proposed aerated lagoon system requires more energy to operate than does the anaerobic lagoon system nearing completion at the existing treatment plant site. Under the no-action alternative, this energy consumption by the proposed plant will not occur.

The no-action alternative will represent a benefit from the standpoint of energy consumption, but at the price of increased flows of untreated sewage in an environmentally unacceptable manner.

6.9 Air Quality, Odors, and Noise

Construction of the proposed treatment plant will result in temporary, localized problems with noise, dust, and construction vehicle exhausts in the immediate vicinity of the construction site and along road corridors leading to the site. These effects would not occur under the no-action alternative. Most of this area, however, is designated for future industrial use, and prevailing winds are expected to direct these emissions from the direction of the city and existing industrial activities. Thus, the benefit is not expected to be significant.

On the other hand, selection of the no-action alternative means that sewage will continue to be treated at the existing site, which is rapidly being encroached upon by new residential neighborhoods. Furthermore, the existing plant is in a location where nearby residences are generally downwind. Anaerobic lagoon treatment systems generate nuisance odors readily. El Saal Drain flows past both informal and established residential areas. Thus, the no-action alternative will continue to produce odor problems in populated areas.

The significance of these effects is not clear. Air quality and odor problems in Suez are already adversely impacted by oil refineries along the northern shore of Suez Bay. Heavy ship traffic in Suez Bay produces emissions as well. With prevailing winds from the north, most of these emissions are quickly driven offshore away from the existing treatment plant and populated areas. When winds come from the south, emissions from the oil refineries probably mask odors from the existing plant except in the immediate vicinity of the plant site.

6.10 Cultural Resources

Cultural resources are not known from the proposed wastewater treatment plant site, but are known in the vicinity of the existing plant. The no-action alternative

means that buried, undiscovered resources at the proposed treatment plant site, if they exist, will remain undisturbed until future development of another type occurs at the site.

If expansion is planned at the existing treatment plant site to accommodate the expected increase in flow, construction would occur in an area closer to known cultural resources. The small risk of disturbance of presently undiscovered resources increases slightly under the no-action alternative if expansion were to occur in the vicinity of the existing WWTP.

CHAPTER 7

7.0 MITIGATION MEASURES

Potentially significant adverse impacts that may result from the proposed action have been identified in Chapter 4. These include:

- o impacts of the wastewater plume on the seawater intake proposed for the Institute of Oceanography and Fisheries research station;
- o effects on nearby land uses if flash floods impact the sludge disposal site and treatment plant; and
- o effects of effluent and sludge disposal on human health.

Mitigation measures that will be incorporated into project design and implementation are described in this chapter. These measures will minimize or eliminate the potential for significant adverse impacts, or partially mitigate for unavoidable impacts.

In addition, Chapter 4 notes the following factors that may be considered in improving environmental soundness of the project, although significant adverse environmental effects are not anticipated at this time:

- o monitoring algal growth in the polishing lagoons and minimizing effects on effluent quality;
- o use of the lagoons by migrating birds and possible problems associated with birds contacting sludge drying lagoons and power lines;
- o use of the existing wastewater treatment plant and its site, and compatibility with surrounding land uses;
- o operational energy consumption;
- o identification and preservation of cultural resources unearthed during construction of the proposed facilities; and
- o effects of outfall construction on sediment transport and shoreline stability.

These are also considered briefly in this chapter. In a few cases, recommendations are provided for consideration by the Egyptian government (NOPWASD or local authorities) for future reference.

7.1 Marine Water Quality

7.1.1 Dispersion and Dilution of the Effluent

The project design includes an outfall located at the 10-m isobath because it provides greater dispersion and dilution of the effluent than a shallower outfall. Preliminary analyses suggest that the wastewater plume occasionally may be blown by east winds toward the fisheries research station. If the research station eventually puts a seawater intake within a few hundred meters offshore of its facility, particulates settling from the wastewater plume could adversely affect the quality of water in the intake during periods of east wind. Furthermore, the preliminary analyses suggest that low-level bacteriological contamination of recreational beaches inshore of the proposed submarine discharge site may occur on occasion.

The use of the 10-m deep outfall is expected to reduce levels of bacteria at the shore to well within Law 48 criteria, but the credibility of the analysis hinges on whether the performance of the wastewater treatment plant meets the assumptions used in the analysis. The analysis clearly shows that the further from shore and deeper the outfall, the better from the standpoint of dispersion and dilution. On the other hand, underwater cables may occur offshore of the proposed treatment plant, and a large area of Suez Bay is designated for ship anchorage. Thus, outfall location must result from a trade-off between the desire to locate as deep and as far from shore as possible as well as avoiding conflict with other activities in Suez Bay.

These potential impacts may be mitigated or eliminated by selecting a deeper discharge depth and by designing a diffuser system for maximum dilution. Discharge into the higher-speed currents found below the 10-m isobath would enhance mixing and dilution of the effluent. A preliminary bathymetric survey conducted as part of the preliminary design study determined that the outfall could not be extended to reach deeper water without interfering with navigation or underwater cables. Thus, an outfall monitoring program is recommended to evaluate dispersion and dilution of the effluent plume.

The monitoring program will be developed by the design/build contractor and incorporated into operation and maintenance manuals and training for the WWTP operators. The monitoring program should include dye studies and monitoring of settleable solids, fecal coliforms, and enterococcus (fecal streptococci) bacteria in the wastewater plume. The program design would focus on documenting plume trajectories, especially during easterly and southerly winds, and decay rates of bacteria

in the plume. Data would be shared with the Institute of Oceanography and Fisheries to assist them in preliminary design of their seawater intake. Local officials will also be able to use the data to close beaches if necessary during certain wind conditions to protect public health.

7.1.2 Effluent Quality

Project design includes constructing and equipping a laboratory. A routine monitoring program should be designed and executed by the laboratory staff to document effluent quality. In addition to monitoring BOD_5, suspended solids, fecal coliforms, and other standard water quality parameters, the program should include monitoring numbers and viability of enterococcus (fecal streptococci) bacteria and the more resistant helminthic pathogens (e.g., *Ascaris* eggs). Analysis of bacteria and pathogens may be done in association with other institutions such as the High Institute of Public Health or the Ministry of Health. The purpose of this monitoring is to establish a database that can be used by the Egyptian government if, in the future, the facilities are expanded or modified with the intent to reuse the effluent for agriculture or aquaculture. The monitoring program will be developed by the design/build contractor and incorporated into operation and maintenance manuals and training programs for the WWTP operators.

7.1.3 Algal Growth and Effluent Quality

The quality of the effluent will be affected in a large part by the amount of algae growing in the facultative and polishing ponds. Submerged multiple draw-off points in the polishing lagoon are proposed as part of project design. Thus, algal growth and control are not expected to be significant problems in maintaining effluent quality. If routine monitoring and analysis of effluent quality, however, indicate that additional measures are required, potential solutions include:

- biological control using aquaculture;
- chemical control; or
- frequent drainage of the polishing ponds.

Chemical control would involve an herbicide, which is designed to be toxic to algae and therefore may have significant adverse impacts on phytoplankton in the zone of initial dilution around the outfall. Chemical control will also increase the rate of sludge production in the ponds by adding large quantities of dead algal biomass. Chemical control is not recommended unless no other alternative is feasible and it is

demonstrated that algal growth is preventing the effluent from meeting Law 48 standards.

Frequent drainage of the polishing ponds may complicate operation of the facility, alter sludge management techniques, and cause nuisance odor problems. Thus, drainage of the polishing ponds is not recommended. On the other hand, the most common natural control for *Bulinus* and *Biomphalaria* snails is the complete drying of the pond for a minimum of 20 days (Pirnie-Harris International 1979). If schistosomias snail vectors become a problem at the Suez treatment plant, this approach to snail control may be used simultaneously to control algae.

Wastewater aquaculture has received considerable attention in recent years. When wastewater is used to support aquaculture operations, the major objective is usually treatment of the wastewater. Systems using aquaculture are believed to effectively lower biochemical oxygen demand (BOD), total suspended solids (TSS), total Kjeldahl nitrogen (TKN), and total phosphorus (Read et al. 1982). The secondary objective is the production of useful biomass. Bivalves and fish are the primary species that have been used. Yields of up to 5,000 kg/ha/yr have been obtained in Israel where *Tilapia* are grown in conjunction with wastewater treatment facilities (Edwards 1985).

There are three advantages of using wastewater for aquaculture. The first is a constant supply of water. Second, the water will contain sufficient nutrients, making supplementary fertilization unnecessary. Finally, in many countries, wastewater treatment facility polishing ponds must be managed for *Anopheles* and *Culex* mosquitoes, *Bulinus* or *Biomphalaria* snails, and various algae. This type of pest management must take place irregardless of any aquaculture practices that are instituted in the pond. Consequently, there is often an operational and economic advantage to combining aquaculture and pest management.

Most investigators recommend that natural measures be employed to control mosquito production in ponds (Middlebrooks 1980). The mosquito fish, *Gambusia,* has been widely used as a natural control in the United States. From a standpoint of using local species and avoiding introduction of non-native species, the use of *Tilapia* is recommended for the Suez treatment plant. *Tilapia* also consume mosquito larvae and can be expected to provide some degree of control of algae (Pirnie-Harris International 1979; Edwards 1985). *Tilapia* is one of the most popular and successfully reared aquaculture species in the Middle East. This species is much hardier than others such as the carp (*Cyprinus carpio)* and grey mullet (*Mugil cephalus)* (Pirnie-Harris International 1979). Although all three species provide natural algal control, *Tilapia* are able to withstand salinities up to 70,000 mg/l and dissolved oxygen values of less than 1 mg/l, both of which may be found in wastewater effluent.

The most significant problem associated with wastewater effluent and this type of aquaculture is the potential for the cultured species to retain human pathogenic

bacteria and/or heavy metals. Edwards (1985) recommends that fish should only be grown in waste stabilization ponds for direct human consumption if the concentration of bacteria in the water does not exceed a concentration of 100 MPN/100 ml. In most cases, this problem is alleviated through depuration in clean-water ponds. The depuration process usually takes several weeks to complete. Under carefully controlled conditions, the public health risk from fish reared in a wastewater treatment effluent may be no greater than uncontrolled harvests of fish in receiving waters of sewage treatment plants (Hejkal et al. 1983). Another alternative is to use the fish produced in the system as fertilizer or feed for livestock. This additional step in the food chain would eliminate direct human consumption, thus providing additional safeguards to human health.

If aquaculture is determined by local officials to be necessary for purposes of algal or mosquito control, the activity should be carried out with participation of the private sector. Public health officials, however, must be involved to ensure the activity is conducted in such a manner that the public health is not endangered.

7.2 Marine Resources

Construction and operation of the wastewater treatment plant should not produce any significant adverse impacts on the plankton, benthos, or fish resources of Suez Bay. Benthic communities will be changed in the narrow corridor occupied by the outfall and in the zone within a few hundred meters around the outfall. Possible changes in abundance and diversity of benthos may occur within a few hundred meters around the outfall, and this may be interpreted as an adverse impact. The major impact, however, will be the elimination of discharge of raw sewage to the bay. Construction of the outfall as well as operation are not expected to have significant adverse impacts on the environment. Consequently the overall quality of the marine resources in Suez Bay should improve slightly, especially near the El Saal Drain.

Many species of resident and migrating waterfowl are also an important component of the marine resources of Suez Bay. Waders in particular use mudflats of Suez Bay as a temporary foraging and resting area during their migrations. Although cessation of discharge of raw sewage across the beach will be a major step in protecting and improving this resource, significant problems with oil pollution in Suez Bay will remain as an adverse impact on these species as well as birds that rest or feed on open marine waters.

Additional improvement of marine resources in Suez Bay can be achieved with an investigation of industrial waste discharges and design of appropriate treatment of industrial wastes. Such a plan may incorporate the existing wastewater treatment plant, which will be made available for other uses by the proposed action. As part of the project, USAID will authorize a study of industrial wastewater treatment needs in Suez. Major objectives of this study should include an inventory of waste streams,

characterization of the discharges, chemical analyses, evaluation of source reduction, and recommended pre-treatment programs.

7.3 Terrestrial and Aquatic Resources

One area of potential concern regarding impact of the proposed action is associated with the ability of the lagoons to attract migrating waterfowl, especially storks, and other birds that use aquatic habitats. These, in turn, will attract some of the migrating predatory birds. As noted in Chapter 4, the sludge drying lagoons at Sharm El Sheikh have trapped and led to the deaths of a significant number of storks during the fall migration. Observations from a wide variety of environments suggest that waterfowl often land on inappropriate surfaces that are shiny and show reflection in a manner comparable to a water body. Floating solid wastes (e.g., plastic bags) in the lagoons at Sharm El Sheikh have occasionally been ingested and led to suffocation or starvation and death.

Overhead power lines are often used as perch sites by raptors. Accidental short-circuiting and death of these birds is likely to occur on occasion, especially with typical design of lower voltage distribution lines. Power lines also pose a collision hazard for birds during periods of low visibility due to fog, dust, or poor air quality.

Loss of storks due to entrapment in sludge or ingestion of solid wastes is not expected to be significant at Suez because the facility at Suez will be equipped with bar screens, which will remove plastic bags and other harmful objects, and the facilities have different waste streams and design. The wastestream at Suez is expected to have significantly less concentrations of cooking oils and fats, and the depth of sludge in the sludge drying lagoons is expected to not be significantly different from that found in sludge drying beds. Thus, entrapment of birds in sludge is not expected.

Since poor visibility is not a common problem at Suez, collisions between birds and the power lines are not expected to be significant sources of mortality. The risk can be further reduced by placing new power lines underground.

Risks of short circuits and electrocution of birds, especially raptors, can be significantly reduced at low cost by providing well insulated perch sites atop existing power poles, erecting taller perching posts nearby, or planting tall-growing trees nearby, which could be watered with treated effluent if salt-tolerant species are selected.

A monitoring program is recommended to ensure that migrating birds do not experience unnecessary or unusual numbers of fatalities at the WWTP. This program should be carried out during the migratory seasons in cooperation with non-governmental organizations concerned with wildlife as well as the Egyptian Wildlife Service. If in the course of monitoring it is determined that storks are being trapped in sludge drying lagoons, the threat may be effectively countered by the temporary use

of netting and fencing to prevent birds from landing on or walking into the sludge lagoons that are in use during the migratory season. The fencing and netting would be of a type commonly used to reduce bird predation at fish hatcheries. The design/build contractor will recommend a monitoring program and include this as part of the O&M procedure at the WWTP.

Presence of floating garbage, especially plastic items, should be monitored frequently during migratory season. All items should be immediately removed from the wastewater lagoons. Solid wastes from the bar screen and grit removers should be stored or disposed of in a manner that minimizes exposure to scavengers near the WWTP. These measures will be incorporated in O&M manuals and emphasized in operator training.

7.4 Land Use

Analyses in Chapter 4 conclude that significant land use impacts are not likely to arise with respect to the proposed action, with the possible exception of the threat of flash flooding in the wadi in which the proposed treatment plant will be located. The use of the existing WWTP site is also an issue that has not been definitively resolved. There are potential uses of the existing WWTP site that may have adverse effects on adjacent land uses.

7.4.1 Flash Floods and Adjacent Land Uses

If appropriate berms and dikes are not constructed at the boundaries of the property, flash floods could course through the sludge disposal site and the wastewater lagoons and carry wastes into the neighboring properties and Suez Bay. Design of such flood prevention structures must not only consider protection of the sludge disposal site and WWTP facilities, but also avoid diverting flood flows into neighboring facilities. Flood risk analyses will be carried out by the design/build contractor, and appropriate design measures will be taken to eliminate this potential impact on adjacent land uses.

7.4.2 Existing WWTP Site and Adjacent Land Uses

In the absence of specific commitments regarding use of the existing WWTP site, USAID may wish to consider negotiated agreements with NOPWASD or the Suez Governorate regarding a range of alternative uses that may or may not be compatible with surrounding land uses.

7.5 Public Health

From a public health point of view, the acceptability of the level of treatment being proposed depends on the method of effluent and sludge disposal, and the potential for subsequent pathogen contact by receiving water or sludge users. Under the proposed design and operations, the public will not be exposed to sludge or effluent at levels or frequencies that may be harmful to health. Monitoring of effluent quality and plume dispersion will verify this conclusion.

The scoping meetings, however, indicate high interest in effluent and sludge reuse (Appendix A). Although these practices are not included in project design, monitoring programs should be initiated by the Egyptian authorities to evaluate levels and survival of pathogens in the effluent and dried sludge.

If monitoring indicates additional measures are needed to protect public health, or if in the future the Egyptian government decides to expand or modify the facilities to include reuse of effluent or sludge, the following points can be taken into consideration with respect to parasite removal, worker safety, and sludge reuse. The basis for decisions will be the data collected under the recommended monitoring program.

7.5.1 Parasite Removal

Improvements in removal of helminth and parasitic cyst pathogens can be achieved by several methods. For example, the use of anaerobic lagoons before aerobic lagoons, or an additional 5-10 days detention time in the polishing ponds, may be effective. Effluent filtration, by either slow or rapid methods, is thought to remove almost all helminth eggs in the effluent (Shuval et al. 1986a). For discharge to Suez Bay, these procedures are not necessary. But if effluent reuse schemes are implemented in the future, the additional treatment may be required to protect public health.

After a preliminary review of the benefits and appropriateness of parasite removal technologies, it is recommended that slow or intermittent sand filtration be seriously considered if effluent reuse is employed at a future date, or if exposure via contact with the receiving waters is determined to be a significant problem. The filtration process will effectively remove the helminths. Reports of aerated lagoons that have been upgraded with intermittent sand filters indicate that significant reductions (75 to 90%) in fecal coliform concentrations can also be achieved (Reynolds et al. 1979). However, such reductions have not always been achieved at other facilities (George 1980). The bacterial removal associated with filtration is thought to be due to the removal of suspended solids in which many of the bacteria are entrapped or to which they are adsorbed. The BOD associated with these solids is also removed, and a high quality effluent typically results.

If fecal coliform concentrations in the effluent are considered too high after filtration, disinfection can then be more effectively achieved due to the reduced interference from the suspended solids. Hypochlorite tablets could be used in this situation with minimal outlay of capital. Other simple chlorination devices have been described by Droste and McJunkin (1982).

7.5.2 Worker Safety

Treatment plant operators may experience a higher incidence of disease than other population groups, although it is thought that the overall risk is low. It is recommended that a medical surveillance program be developed in cooperation with local health officials to ensure that all operators are properly immunized and are trained to maintain high levels of personal hygiene. Antihelminthic drugs are available and have proved effective if reinfection can be prevented. Iron supplements can alleviate the anemia of individuals who are suffering from hookworm infections until the exposure to the disease can be reduced (Walton 1981).

Provision of protective clothing for workers likely to come into contact with pathogens is recommended. Laundry facilities for workers clothing to prevent transmission of pathogens to workers' homes and families should be considered. The use of rubber or plastic footwear has been demonstrated to significantly reduce the occurrence of hookworm in agricultural workers in the Nile area. Use of protective footwear should be mandatory, especially for workers in the sludge drying lagoons.

Appropriate measures to protect and monitor worker health and safety will be incorporated by the design/build contractor in the operations and maintenance manual and training program for the WWTP operators.

7.5.3 Sludge Reuse

Sludge reuse is not part of current project design. If in the future the Egyptian government decides to implement this practice, additional treatment of the sludge is recommended before local farmers are permitted to use the sludge as fertilizer or soil conditioner. The two main factors related to cyst and helminth egg survival are temperature and moisture content. Availability of oxygen is also a factor. Anaerobic stabilization such as occurs at the bottom of the partial mix lagoon tends to inhibit egg development, while aerobic digestion may accelerate it (El-din Hassan 1988).

Inactivation of pathogens, and *Ascaris* in particular, can be reliably achieved by storage at temperatures higher than 55°C (Reimers et al. 1986). Such inactivation may be achieved economically by high temperature (aerobic) composting or solar heating and result in a safe product.

To reduce the possibility of *Ascaris* egg survival and reinfection, dried sludge should be spread on dedicated land for 6 months to 1 year before allowing local farmers to remove the sludge for their own purposes. Plant operators should periodically test the sludge and document the occurrence and viability of *Ascaris* eggs in this material. Sludge that contains viable eggs should not be used in areas where reinfection can occur.

The need for additional drying and storage would be negated by the use of a composting operation. Sludge tends to be high in nitrogen content but is generally considered a low-grade fertilizer due to other mineral limitations. Finding composting bulking agents in Egypt (wood chips and saw dust are often used elsewhere) may be a problem. Garbage has a high organic content and has good bulking qualities. Co-composting of these two materials produces a good, useful product. While the provision of composting is considered outside the scope of this project, the Suez Governorate may want to evaluate this option in the future in context with its waste management plans to determine if this would be beneficial to Suez. Obeng and Wright (1987) provide a good review of the methods, benefits, and feasibility of composting and co-composting sludge with garbage in developing countries.

7.6 Energy

Of the treatment alternatives that appear economically to be the most feasible (trickling filter, conventional activated sludge, and aerated lagoons; Chapter 2), the proposed aerated lagoon system is the most reliable system but also the most energy-intensive to operate (Section 4.10). A tariff study is underway that will assist the Suez Governorate in ameliorating impact of increased O&M costs. The issue of funding support for O&M is included in Grant Agreements for the project.

Features that might improve energy efficiency or make use of low-cost, low-technology wind or solar power sources should be considered by the design/build contractor during final project design. Proper sizing and evaluation of losses of efficiency in transformers and electric motors will help achieve optimum mix of capital and operating energy cost. Energy efficient motors and transformers should be required. Operational activities will include energy efficiency as a factor, e.g., aerators could be operated in cycles rather than constantly.

Obtaining electrical feed from two different sources may be more desirable than providing standby diesel generators, as the latter will require major overhauls at regular intervals and therefore will be out of service for extended periods of time.

7.7 Cultural Resources

Although no cultural resources are known to occur within the proposed project site, the potential exists for encountering subsurface resources. If any suspected cultural resources or historical artifacts are uncovered during project construction, all work in the immediate area should be stopped and a qualified archeologist consulted for recommendations. These recommendations should be implemented by the design/build contractor in consultation with Egyptian officials in the Department of Antiquities, Ministry of Culture, in Cairo.

7.8 Geology and Soils

The potential for interruption of normal littoral sediment transport process will be reduced if the submarine outfall line is buried below normal grade as it crosses the beach and nearshore zones.

REFERENCES

Adams, A. 1989. Ambush! Cairo Today 10(10):78-80.

Adler, R.W. 1990. Policy Issues in the Energy Sector. Unpubl. report. USAID/Cairo.

Anderson, J. 1898. *Reptilia and batrachia.* Zoology of Egypt, Vol I. Bernard Quaritch, London.

Anon. 1985. Assessment of the oil spills on the coast of the Red Sea and their impact on its biota. Academy of Scientific Research and Technology, Institute of Oceanography and Fisheries, Cairo.

Avery, M.L. (ed.) 1978. Impacts of transmission lines on birds in flight. FWS/OBS-78/48, US Fish and Wildlife Service, Washington, DC. 151 pp.

Awad, H., P. Michel, and A. El-Shazly 1983. Actual situation of oil pollution in the ecosystem along the Egyptian Red Sea coast. Bull. Inst. Oceanogr. Fisheries, Arab Rep. Egypt 9:102-108.

Baha El Din, S. and M.A. Saleh. 1983. Report on the ornithological results of the Egyptian Red Sea pollution expedition, October - December, 1982. Ornithological Society of Egypt.

Baldwin, M.F., D. Ferguson, K.A. Saterson, and I.E. Wallen. 1988. The Biological Resources of the Arab Republic of Egypt Status and Recommended Conservation Needs. Prep. for USAID/Cairo, Office of Science and Technology.

Behairy, A.K.A. and M.A.H. Saad. 1984. Effect of pollution on the coastal waters of the Red Sea in Front of Jeddah, Saudi Arabia -Environmental Conditions. Tethys 11:111-117.

Beltagy, A.I. and K.A. Moussa. 1984. The distribution of organic matter in the sediments of the Gulf of Suez. Bull. Inst. Oceanogr. Fisheries, Arab Rep. Egypt 10:99-109.

Bijlsma, R.G. 1983. The migration of raptors near Suez, Egypt Autumn, 1981. Sandgrouse 5:19-44.

Borman, F.W. 1929. An ornithological trip in the Gulf of Suez and Red Sea. Ibis Ser. 12(5):639-50.

Bowles, D.S., E.J. Middlebrooks, and J.H. Reynolds. 1979. Coliform decay rates in waste stabilization ponds. JWPCF 51:87-99.

Brayton, P., D. Roszak, S.A. Huq, L.M. Palmer, D.J. Grimes, and R.R. Colwell. 1984. Public health significance of human pathogens in the ocean. Proc. Oceans '84, Marine Tech. Soc., pp. 263-267.

British Admiralty. 1955. Red Sea and Gulf of Aden Pilot. Hydrographic Department, British Admiralty, London.

Brooks, J.L., C.A. Rock, and R.A. Struchtemeyer. 1984. Use of peat for on-site wastewater treatment: Part I, Laboratory evaluation, and Part II, Field studies. J. Env. Qual. 13:518-530.

Brown, L., A. Durning, C. Flavin, H. French, J. Jacobsen, M. Lowe, S. Postel, M. Renner, L. Starke, and J. Young. 1990. State of the World 1990. W.W. Norton & Co., New York.

Bruun, B. 1989. The migration of birds of prey in Egypt. Courser 2:5-13.

Cabelli, V.J. 1983. Health Effects Criteria for Marine Recreational Waters. EPA 600/1-80-031, US Environmental Protection Agency, Cincinnati, OH.

_____. 1989. Swimming-associated illness and recreational water quality criteria. Water Sci. Tech. 21:13-21.

CAPMAS. 1986. Census Data for 1986. CAPMAS, Cairo, Egypt.

Clark, C.S. 1984. Health effects associated with wastewater treatment and disposal. JWPCF 56:625-627.

CMC. 1989. Canal Cities - Phase II Project Population and Flow Study. Prep. for USAID/Cairo.

Colwell, R. 1981. Use of the Oceans for Man's Wastes: Engineering and Scientific Aspects. Proceedings of a symposium. Marine Board Assembly of Engineering, National Research Council. National Academy Press., Washington, DC. 300 pp.

Dames & Moore. 1985. Sinai Development Study. Prep. for the Egypt Ministry of Development, USAID Grant No. 263-0113.

_____. 1989. Geotechnical investigation: Deep shaft treatment option. Prep. for CMC and NOPWASD, Cairo, Egypt.

_____. 1990. Technical Report on Water Quality Analyses for the City of Suez. Prep. for USAID/Cairo. 64 pp + app.

Diab, A.M.M. 1989. Fishes as a possible marine parameter for bacterial pollution in the Suez Canal region. Ph.D. Thesis submitted to the Suez Canal University.

Diamant, B.Z. 1980. Environmental repercussions of irrigation development in hot climates. Env. Conserv. 7:53-58.

Diamond, A.W., R.L. Schreiber, D. Attenborough, and I. Prestt. 1987. Save the birds. Cambridge University Press, Cambridge.

Dicks, B. 1987. Pollution. In: Edward, A.J. and S.M. Head (eds.) Key Environments: Red Sea. Pergammon Press.

Dicks, B. and J.P. Hartley. 1982. The effects of repeated small oil spillages and chronic discharges. Phil. Trans. R. Soc. Lond. B 297:285-307.

Diggelen, R.V. et al. 1984. Raptor migration over Suez in the autumn of 1984. Unpublished report.

Dowidar, N.M. 1976. The phytoplankton of the Suez Canal. Acta Adriatica 18:241-256.

Droste, R.L. and F.E. McJunkin. 1982. Simple water treatment methods. Pp. 101-122 In: Water Supply and Sanitation in Developing Countries. Ann Arbor, MI.

Edwards, A.J. and S.M. Head (eds) 1987. Key Environments: Red Sea. Pergammon Press. 441 pp.

Edwards, P. 1985. Aquaculture: A component of low cost sanitation technology. Technical Paper No. 36, World Bank, Washington, DC. 45 pp.

El Awady, M.M. 1981. Evaluation of pollutant elements in the Egyptian shores and harbors by advanced analytical methods. Ph.D. thesis, Univ. Cairo.

El-Din, S.H.S. 1975. Variation of sea level on the Egyptian Mediterranean and Red Sea Coasts. Intern. Hydro. Rev. 52:62-73.

El-din Hassan, A.H. 1988. Management of different sewage sludges on drying beds with emphasis on public health aspects. Thesis, High Institute of Public Health, Alexandria, Egypt.

El-Sabh, M.I. 1967. Hydrography of Suez Canal. M. S. thesis, Cairo Univ., Faculty of Science. 167 pp.

El Samra, M.I., K.Z. El Deeb, A.I. Askar, S.D. Wahby, and M.S.H. El Shazly. 1983. Preliminary study of petroleum pollution along the Suez Canal. Bull. Inst. Oceanogr. Fisheries, Arab Rep. Egypt 9:97-101.

El Sharkawi, F. 1986. The pollution of the beaches of Alexandria due to the discharge of sewage: A case study. Water Sci. Tech. 18:273-278.

Esvelt, L.A., W.J. Kaufman, and R.E. Selleck. 1971. Toxicity removal from municipal waste waters. In: A Study of Toxicity and Biostimulation in San Francisco Bay-Delta Waters, Vol IV. SERL Rept. No. 71-7. San. Eng. Res. Lab., Univ. of Calif. Berkeley, CA. 153 pp + appendix.

Euroconsult-Pacer Consultants. 1985. Land Master Plan. Prep. for GARPAD, Egypt Ministry of Agriculture and Land Reclamation, Cairo, Egypt.

Fattal, B., E. Peleg-Olevsky, Y. Yoshipe-Purer, and H.I. Shuval. 1986. The association between morbidity among bathers and microbial quality of seawater. Water Sci. Tech. 18:56-69.

Ferguson, D.A. 1983. Management of Egyptian Red Sea marine resources. Bull. Inst. Oceanogr. Fisheries, Arab Rep. Egypt 9:461-467.

Finlayson, B.J. and L.A. Hinkelman. 1977. Effects of chlorinated power plant cooling water on aquatic biota. Administrative Report No. 77-5, Environmental Services Branch, Calif. Dept. of Fish and Game, Sacramento, CA. 53 pp.

Fishelson, L. 1971. Ecology and distribution of the benthic fauna in the shallow water of the Red Sea. Mar. Biol. 10:113-133.

Frazier, J., G.C. Bertram, and P.G. Evans. 1987. Turtles and Marine Mammals. In: Edward, A.J. and S.M. Head (eds.) Key Environments: Red Sea. Pergammon Press.

Frazier, J.G. and M.A. Salas. 1984. The status of marine turtles in the Egyptian Red Sea. Biological Conservation 30:41-67.

Garunkstis, B. 1986. Master plan for rehabilitation, modernization and expansion of the Port of Suez. In: Proc. Ports '86 Conf., Amer. Soc. Civil Eng., New York.

Gentile, J.H., J. Cardin, M. Johnson, and S. Sonnowski. 1976. Power plants, chlorine, and estuaries. EPA-600/3-76-055, Environmental Protection Agency, Washington, DC. 28 pp.

Geogroup. 1982. Rehabilitation and Expansion of the Canal Cities Wastewater Systems, Supplement to Design Reports No. 2. Prep. for USAID/Cairo.

George, D.B. 1980. Lagoons and oxidation ponds. JWPCF 52:1177-1181.

Gilmer, D.S. and J.M. Wiehe. 1977. Nesting by ferruginous hawks and other raptors on high voltage powerline towers. Prairie Naturalist 9:1-10.

Goldberg, S.D. 1979. Domestic Wastewater Reuse for Agriculture, Opportunities and Methods: A Primer. PUN 51-T, World Bank Transportation, Water and Telecommunications Department, Washington, DC.

Goodman, S.M. and P.L. Meininger (eds.) 1989. The Birds of Egypt. Oxford University Press, Oxford.

Goodwin, D. 1949. Notes on the migration of birds of prey over Suez. Ibis 91:56-63.

Grice, G.D. and A.D. Hart. 1962. The abundance, seasonal occurrence and distribution of the epizooplankton between New York and Bermuda. Ecol. Monogr. 32:287-309.

Gunnerson, C.G. (ed.) 1988. Wastewater Management for Coastal Cities: The Ocean Disposal Option. World Bank Tech. Paper No. 77.

Heinle, D.R. 1969. Temperature and zooplankton. Chesapeake Sci. 10:186-209.

Hejkal, T.W., C.P. Gerba, S. Henderson, and M. Freeze. 1983. Bacteriological, virological and chemical evaluation of a waste-water aquaculture system. Water Res. 17:1749-1755.

Herman, S.S. and J.R. Beers. 1969. The ecology of inshore plankton populations in Bermuda. Part II. Seasonal abundance and composition of the zooplankton. Bull. Mar. Sci. 19:483-503.

Hoss, D.E., L.C. Coston, J.P. Baptist, and D.W. Engel. 1974. Effects of temperature, copper, and chlorine on fish during stimulated entrainment in power plant condenser cooling systems. Proc. of Symposium, Oslo. Int. A.E.C., Vienna. 519 pp.

Icanberry, J.W. 1973. Zooplankton survival in cooling water systems of four California coastal power plants in August 1971-July 1972. 36th annual meeting of the Am. Soc. of Limn. and Ocean., Inc. 53 pp.

Jennings, M.C., P.C. Heathcote, D. Parr, and S.M. Baha el Din. 1985. Ornithological survey of the Ras Dib area and the islands at the mouth of the Gulf of Suez, Egypt. Oil Pollution Research Unit, Pembroke.

Johnston, R. 1976. Marine pollution. Academic Press, New York.

Kassas, M. 1953. Habitat and plant communities in the Egyptian desert, II. The features of a desert community. J. Ecol. 41:248-256.

Kassas, M. and M.A. Zahran. 1962. Studies on the ecology of the Red Sea coastal land, I. The district of Gebel Ataqa and El-Galala El-Bahariya. Bull. Soc. Geogr. d'Egypte 35:129-75.

Lindstrom, K.P. 1986. Viruses in wastewater and the marine environment: An issue paper. Prep. for Combined Sanitation Districts of Orange County, Fountain Valley, CA.

Mancy, K.H. 1983. Assessing potential marine pollution in the Red Sea. Bull. Inst. Oceanogr. Fisheries, Arab Rep. Egypt 9:89-96.

Marias, G.R. 1974. Faecal bacterial kinetics in stabilization ponds. J. Env. Eng. 100:119-137.

Marine Environmental Services, Inc. 1979. Oceanographic studies, Suez. In: Pirnie-Harris International. Suez Wastewater Facilities Master Plan. Prep. for USAID/Cairo and Ministry of Housing and Reconstruction, Arab Republic of Egypt.

Marx, H. 1968. Checklist of the reptiles and amphibians of Egypt. United States Naval Medical Research Unit Number Three, Cairo.

Mearns, A.J. and C.S. Greene. 1976. Comparison of the benthos at several wastewater discharge sites. Pp. 211-216 In: Coastal water research project annual report 1976. Southern California Coastal Water Research Project, El Segundo, CA.

Meininger, P.L. and W.C. Mullie'. 1981. The significance of Egyptian wetlands for wintering waterbirds. The Holy Land Conservation Fund, New York.

Merchant, S. 1941. Notes on the birds of the Gulf of Suez. Ibis Ser. 14(5):265-295, 378-396.

Meshal, A.H. 1967. A physical study of water pollution in Suez Bay (hydrography of Suez Bay). M.S. thesis, Cairo Univ., Faculty of Science. 109 pp.

_____. 1970. Water pollution in Suez Bay. Bull. Inst. Oceanogr. and Fisheries, Arab Rep. of Egypt 2:462-473.

_____. 1975. Brine at the bottom of the Great Bitter Lake as a result of closing the closing Suez Canal. Nature 256:297-298.

Metcalf and Eddy, Inc. 1979. Wastewater Engineering: Treatment, Disposal, Reuse. McGraw Hill, New York.

Middlebrooks, E.J. 1980. Aquatic plant processes assessment. In: Aquaculture Systems for Wastewater - An Engineering Assessment. EPA 430/9-80-007, US Environmental Protection Agency, Washington, DC.

Middlebrooks, E.J., J. Reynolds, and C.H. Middlebrooks. 1979. Performance of aerated wastewater stabilization ponds. In: Middlebrooks, E.J., D.H. Falkenborg, and R.F. Lewis (eds.) Performance and Upgrading of Wastewater Stabilization Ponds: Proceedings of a Conference. EPA-600/9-79-011, US Environmental Protection Agency, Cincinnati, OH.

Ministry of the USSR Fisheries. 1966. Report on work of Azcherniro Expedition on R/V "Ichtiolog", Vol.II. Azov and the Black Sea Scientific Research Institute of Sea Fisheries and Oceanography.

Morcos, S.A. 1970. Physical and chemical oceanography of the Red Sea. Oceanogr. Mar. Biol. Ann. Rev. 8:73-202.

Morcos, S.A. and T.P. Riley. 1966. Chlorinity, salinity, density, and conductivity of sea water from the Suez Canal region. Deep-Sea Res. 13:741-749.

Mountfort, G. 1988. Rare Birds of the World. Collins / International Council for Bird Preservation, London.

Moursy, A. 1978. A Field Study of Oil Pollution of the Egyptian Coast of the Red Sea. National Research Center, Cairo, Egypt.

Nichols, D.S. and D.H. Boelter. 1982. Treatment of secondary sewage effluent with a peat-sand filter bed. J. Envtal Qual. 11:86-92.

Obeng, C. and F. Wright. 1987. The Co-composting of Domestic Solid and Human Wastes. World Bank Tech. Paper No. 57.

Osborn, D.J. and I. Helmy. 1980. The contemporary land mammals of Egypt (including Sinai). Fieldiana: Zoology, New Ser. No. 5.

Pahren, H.R. and W. Jakubowski. 1987. Health aspects of wastewater aerosols. Water Sci. Tech. 13:1091-1096.

Patzert, W.C. 1972. Seasonal variations in structure and circulation in the Red Sea. Ph.D. thesis, Univ. of Hawaii.

_____. 1974. Wind-induced reversal in Red Sea circulation. Deep-Sea Res. 21:109-121.

Payment, P. 1989. Virus removal by drinking water treatment processes. Critical Reviews in Environmental Control 19:15-31.

Pirnie-Harris International. 1979. Suez Wastewater Facilities Master Plan. Prep. for the Ministry of Development and New Communities, Arab Republic of Egypt, and USAID/Cairo.

Read, P.A., K.J. Anderson, J.E. Matthews, P.G. Watson, M.C. Halliday, and G.M. Shields. 1983. Effects of pollution on the benthos of the Firth of Forth. Mar. Poll. Bull. 14:12-16.

Reimers, R.S., D.B. McDonell, M.D. Little, D.D. Bowman, and A.J. Englande. 1986. Effectiveness of wastewater sludge treatment process to inactivate parasites. Water Sci. Tech. 18:397-404.

Reynolds, J.H., J. Russell, and E.J. Middlebrooks. 1979. Intermittent sand filtration to upgrade lagoon effluents. In: Middlebrooks, E.J., D.H. Falkenborg, and R.F. Lewis (eds.) Performance and Upgrading of Wastewater Stabilization Ponds: Proceedings of a Conference. EPA-600/9-79-011, US Environmental Protection Agency, Cincinnati, OH.

Roberts, M.H. Jr., R.J. Diaz, M.E. Bender, and R.J. Huggett. 1975. Acute toxicity of chlorine to selected estuarine species. J. Fish. Res Bd. Can. 32:2525-2528.

Rose, J.B. 1986. Microbial aspects of wastewater reuse for irrigation. Critical Reviews in Environmental Control 16:231.

Salas, H.I. 1986. History and application of microbiological water quality standards in the marine environment. Water Sci. Tech. 18:47-57.

Sarikaya, H.Z., A.M. Saatci, and A.F. Abdulfattah. 1987. Effect of pond depth on bacterial die-off. J. Env. Eng. 113:1350-1362.

Sawyer, T.K. and E.J. Lewis. 1989. Sewage-associated protozoans (Amoebida) and bacteria as indicators of the sanitary quality of commercial shellfish beds. Pp. 73-81 In: Hood, D.W., A. Schoener, and P.K. Park (eds.) Oceanic Processes In Marine Pollution, Vol 4: Scientific Monitoring Strategies For Ocean Waste Disposal. Robert E. Krieger Publishing Company, Malabar, Florida.

Severin, B.F. 1980. Disinfection of municipal wastewater effluents with ultraviolet light. JWPCF 52:2007-2018.

Shaw, D.G. 1988. Hydrocarbon accumulations. Pp. 243-265 In: Shaw, D.G. and M.J. Hameedi (eds.). Environmental studies in Port Valdez, Alaska. No.24, Lecture Notes on Coastal and Estuarine Studies. Springer-Verlag, Berlin. 423 pp.

Shuval, H.I., A. Adin, B. Fattal, E. Rawitz, and P. Yekutiel. 1986(a). Wastewater Irrigation in Developing Countries: Health Effects and Technical Solutions. World Bank Tech. Paper No. 51.

Shuval, H.I., B. Fattal, and P. Yekutiel. 1986(b). State of the art review: An epidemiological approach to the health effects of wastewater reuse. Water Sci. Tech. 18:147-162]

Stone, R.W., W.J. Kaufman, and A.J. Horne. 1973. Long-term effects of toxicants and biostimulants on the waters of central San Francisco Bay. Report No. 73-1, Univ. of Calif. Sanitary Engineering Research Laboratory, Richmond, CA.

Strauss, M. 1985. Survival of excreted pathogens in excreta and fecal sludge. IRCWD News 23: 4-9.

Trussell, R.P. 1972. The percent un-ionized ammonia in aqueous ammonia solutions at different pH levels and temperatures. J. Fish. Res. Bd. Canada 29:10-12.

UNEP. 1986. Action Plan for the Conservation of the Marine Environment and Coastal Areas of the Red Sea and Gulf of Aden, UNEP Regional Seas Reports and Studies No. 81, United Nations Environmental Programme, Nairobi, Kenya.

_____. 1987. Convention on the conservation of migratory species of wild animals: (CMS). Proceedings of the first meeting of the conference of the parties, Vol. I. United Nations Environmental Programme, Nairobi, Kenya.

UNESCO. 1976. Marine science programme for the Red Sea. UNESCO Tech. Papers in Mar. Sci. No. 25.

USAID. 1985. Arab Republic of Egypt, Canal Cities Water and Sewerage Project - Phase II (263-0174), Project Identification Document. Bureau for Asia and Near East, US Agency for International Development, Washington, DC.

_____. 1987. Project Paper Canal Cities Water and Wastewater Phase II Project No. 263-0174. USAID/Cairo.

US Environmental Protection Agency. 1980. Guidelines for Water Reuse, EPA-600/8-80-036. US Environmental Protection Agency, Washington, DC.

_____. 1982. Design of 301(h) Monitoring Programs for Municipal Wastewater Discharges to Marine Waters. US Environmental Protection Agency, Washington, DC. 135pp.

_____. 1986a. Ambient Water Quality Criteria for Bacteria - 1986. EPA 440/5-84-002, Office of Water Regulations and Standards, US Environmental Protection Agency, Washington, DC.

_____. 1986b. Quality Criteria for Water - 1986. EPA 440/5-86-001, Office of Water Regulations and Standards, US Environmental Protection Agency, Washington, DC.

US National Ocean Survey. 1988. Tide Tables, High and Low Water Predictions, Western Pacific Ocean and Indian Ocean, 1989. Nat. Oceanic and Atmosph. Admin., US Dept. Comm., Rockville, MD.

US Naval Weather Service Command. 1974a. Summary of synoptic meteorological observations, East African and selected island coastal marine areas. Vol. 2, Area 11: Red Sea North. US Navy Weather Service Detachment, Asheville, NC.

_____. 1974b. Climatic summaries for major Indian Ocean ports and waters. Publ. NAVAIR 50-1C-63, US Navy Weather Service Detachment, Asheville, NC.

Walton, S. 1981. Egypt after the Aswan Dam. Environment 23:30-36.

Whimpfheimer, D., B. Bruun, S.M. Baha El Din, and M.C. Jennings. 1983. The migration of birds of prey in the northern Red Sea area. The Holy Land Conservation Fund, New York.

Whistler, H. 1916. Migration notes from a passage streamer. Zoologist 20:453-458.

Wolfson, A., G. Van Blaricom, N. Davis, and G.S. Lewbel. 1979. The marine life of an offshore oil platform. Mar. Ecol. Prog. Ser. 1:81-89.

Woodmansee, R.A. 1958. The seasonal distribution of the zooplankton off Chicken Key in Biscayne Bay, Florida. Ecology 39:247-262.

Word, J.Q. 1979a. Marine environmental assessment aided by the use of the infaunal tropic index. Pp. 41-58 In: Siva, J., E. Birchard, K. Guziak, D. Chamberlain, and G. Cox (eds.) Proceedings of the Ecological Damage Assessment Conference, Society of Petroleum Industrial Biologists. American Petroleum Institute, Washington, DC.

_____. 1979b. The infaunal trophic index. Pp. 19-39 In: Coastal water research project annual report 1978. Southern California Coastal Water Research Project, El Segundo, CA.

Word, J.Q., A.J. Mearns and B.L. Myers. 1977. Animals that are indicators of marine pollution. Pp. 199-206 In: Coastal water research project annual report 1977. Southern California Coastal Water Research Project, El Segundo, CA.

World Bank. 1989. Egypt Land Reclamation Subsector Review. Report No. 8047-EGT. World Bank, Washington, DC.

World Health Organization. 1973. Reuse of Effluents: Methods of Wastewater Treatment and Health Safeguards. WHO Technical Report Series No. 517. World Health Organization, Geneva, Switzerland.

_____. 1989. Health Guidelines for the Use of Wastewater in Agriculture and Aquaculture. Tech. Rept. Ser. 778. World Health Organization, Geneva, Switzerland.

World Health Organization/United Nations Environmental Programme. 1989. Consultation on Guidelines for Submarine Outfalls in the Mediterranean. EUR/ICP/CEH 085(S), World Health Organization, Geneva, Switzerland.

Zahran, M.A. 1977. On the ecology of halophytic vegetation of Egypt. Bull. Fac. Sci. Mansoura University No. 4.

LIST OF PERSONS CONTACTED

Abdullah, M. National Institute of Oceanography and Fisheries. Cairo, Egypt. Meeting, 18 February 1990.

Adams, A. Meeting, April 1990.

Adamson, T. Suez Canal University/Liverpool University Joint Marine Biology Project (EEC), Ismailia, Egypt. Meeting, 13 February 1990.

Allen, B. San Francisco Bay Regional Water Quality Control Board, Oakland, CA, USA. Telecom, 26 April 1990.

Archer, B. Office of Technical Resources, Bureau for Asia and Near East, US Agency for International Development, Washington, DC, USA. Telecom, 12 April 1990.

Bahgat, M.M. Suez Canal University, Ismailia, Egypt. Meeting, 11 February 1990.

Ballentine, K. Office of Water Regulations and Standards, US Environmental Protection Agency, Washington, DC, USA. Telecom, 4 May 1990.

Bastian, B. US Environmental Protection Agency, Washington, DC, USA. Telecom. 24 April 1990.

Bebars, E. Director, Red Sea and Suez Canal Branch, National Institute of Oceanography and Fisheries, Suez. Meeting, 27 November 1989.

Best, M. Suez Canal University/Liverpool University Joint Marine Biology Project (EEC), Ismailia, Egypt. Meeting, 13 February 1990.

Bishop, F. Biosystems Branch, Water and Hazardous Waste Research Division, EPA, Cincinnati, OH, USA. Telecom. 24 April 1990.

Cabelli, V. Department of Microbiology, University of Rhode Island, Providence, RI, USA. Telecom, 9 May 1990.

Cingel, K. Atkins, Inc., Advisor to GARPAD, Ministry of Agriculture and Land Reclamation, Cairo, Egypt. Meeting, 29 January 1990.

Colwell, R. University of Maryland. Telecom, 8 May 1990.

Dewedar, A. Vice President, Suez Canal University, Ismailia, Egypt. Meeting, 13 February 1990.

Diab, A. Suez Canal University, Ismailia, Egypt. Meeting, 11 February 1990.

Dong, K. James M. Montgomery Consulting Engineers, Pasadena, CA, USA. Memorandum to Ron Westervelt (JMM), 12 April 1990.

Dufour, A. Environmental Monitoring Systems Laboratory, US Environmental Protection Agency, Cincinnati, OH, USA. Telecom, 8 May 1990.

El Eisawy, A.M. National Institute of Oceanography and Fisheries, Academy of Scientific Research and Technology, Cairo, Egypt. Meeting, 18 February 1990.

El Housseini, M. Agricultural Research Center, Soil and Water Research Institute, Cairo, Egypt. Meeting, 19 February 1990.

El Sayih, Hiragy Hassan Director, Governorate of Suez Wastewater Department, Suez. Meeting, 4 February 1990.

El Siringawy, D. Scientific Research Academy, Cairo, Egypt. Meeting, 21 February 1990.

Fahmy, ? Deputy Director, National Institute of Oceanography and Fisheries Research Station, Suez, Egypt. Meeting, 11 February 1990.

Farghaly, M.E.S. Suez Canal University, Ismailia, Egypt. Meeting, 13 February 1990.

Faris, M. Director, Governorate of Ismailia Wastewater Department, Ismailia, Egypt. Meeting, 4 February 1990.

Fouda, M. El Azhar University, Cairo, Egypt. Meeting, 20 February 1990.

French, J. Camp Dresser McKee, Boston, MA, USA. Telecom, 9 May 1990.

Gaines, J. Shellfish Sanitation Branch, Food and Drug Administration, North Kingstown, RI, USA. Telecom, 8 May 1990.

Galmer, B. Public Works Department, City of Arcata, CA, USA. Telecom, 23 April 1990.

Hartnoll, R. Suez Canal University/Liverpool University Joint Marine Biology Project (EEC), Ismailia, Egypt. Meeting, 13 February 1990.

Haydock, I. Compliance Division Manager, Technical Services Department, County Sanitation Districts Orange County, Fountain Valley, CA, USA. Telecom, 24 April 1990

Ichord, R. Energy and Natural Resources Division, Office of Technical Resources, Bureau for Asia and Near East, USAID, Washington, DC, USA. Telecom, 14 May 1990.

Kawata, K. Public Health Specialist/USAID Consultant, Baltimore, MD, USA. Memo to Paul Thorn, USAID/Cairo, 13 July 1990.

Kinzelbach, R.K. Ecology and Zoology Professor, Darmstadt Technical Institute, Darmstadt, West Germany. Meeting, 15 April 1990.

Kisseiba, M. Director, Sanitary Drainage Laboratory, Ismailia, Egypt. Meeting, 13 February 1990.

Lindstrom, K.P. President, K.P. Lindstrom, Inc., Sacramento, CA, USA. Telecom, 2 April 1990.

Lintner, S.F. Environment Department, Europe, Middle East & North Africa Regional Office, World Bank, Washington, DC, USA. Telecom, 4 April 1990.

Lung, W.-S. Envirotech Associates, Inc., Charlottesville, VA, USA. Meeting, 10 March 1990.

Naghmoush, S. Director, GARPAD, Ministry of Agriculture and Land Reclamation, Cairo, Egypt. Meeting, 29 January 1990.

Shadid, Y. General Organization of Physical Planning, Ismailia, Egypt. Meeting, 26 February 1990.

Shafie, A.A. Chief Toxicologist, Environmental & Occupational Health Center, Ministry of Health, Cairo, Egypt. Meeting, 4 December 1989.

Shaker, A. Director, Environmental & Occupational Health Center, Ministry of Health, Cairo, Egypt. Meeting, 4 December 1989.

Stuggins, G. Europe, Middle East & North Africa Regional Office, World Bank, Washington, DC, USA. Telecom, 12 April 1990.

Suer, A.L. San Francisco Bay Regional Water Quality Control Board, Oakland, CA, USA. Telecom, 26 April 1990.

Zanati, G. GARPAD, Ministry of Agriculture and Land Reclamation, Cairo, Egypt. Meeting, 29 January 1990.

Zeld, H.A. Office of Environmental Affairs, Governorate of Suez, Suez, Egypt. Meeting, February 1990.

LIST OF FREPARERS

William Paratore	Project Director
Harvey Van Veldhuizen, Ph.D.	Project Manager, Water Quality, Marine Ecology
Lee Fausak	Oceanography, Water Quality
Jim Salevan	Marine Resources
Sharif Baha El Din	Terrestrial Resources
Mindy Baha El Din	Terrestrial Resources
Paul Jarrett	Public Health
Douglas Gritzinger	Land Use, Cultural Resources
Cliff Pomerantz	Energy, Alternatives Description
Ron Bizzarri	Energy, Alte.natives Description
Mel Rice	Geology, Groundwater
Shane Rosenthal	International Conventions on the Environment; Egyptian Environmental Regulations
Dana Younger	USAID Environmental Procedures, Chief Environmental Advisor

APPENDIX A
SCOPING REPORT

SCOPING REPORT
ENVIRONMENTAL ASSESSMENT OF A NEW WASTEWATER TREATMENT PLANT PROPOSED FOR SUEZ CITY

Government of Egypt-U.S. Agency for International Development:
Canal Cities Water and Wastewater Project
Phase II

INTRODUCTION

Egypt's National Organization for Potable Water Supply and Sanitary Drainage (NOPWASD), in association with the United States Agency for International Development (USAID), is proposing to build a new sewage treatment plant for Suez City. The proposed treatment plant is one element of the Canal Cities Water and Wastewater Project Phase II, partially funded by USAID. Phase II of the project continues more than a decade of effort to rehabilitate Suez's war-damaged wastewater system, and provides capacity for future urban growth of this important region.

NOPWASD and USAID tentatively agree that an Aerated Lagoon treatment method should be used by the proposed Suez wastewater treatment plant, basing their decision on considerations of cost, simplicity of operation, land requirements, and effluent quality. The treatment plant will vastly improve the quality of urban wastewater flowing into Suez Bay from Suez City. Nevertheless, proposed construction of the new facilities has raised several environmental concerns that require further analysis.

NOPWASD is conducting an Environmental Assessment of the proposed new sewage treatment plant for Suez City. An Environmental Assessment (EA) provides decision-makers with information concerning: existing environmental conditions, potential environmental impacts of the proposed project's construction and operation, possible mitigating measures, monitoring programs, opportunities for environmental enhancement, and environmental management plans.

As part of preparation of the EA, scoping meetings were held in Cairo on 8 February and in Suez City on 11 February 1990. The purpose of the scoping meetings was to bring together all parties with an interest in Suez City's proposed new wastewater treatment plant to assist NOPWASD in identifying environmental issues that should be addressed by the EA. The scoping meeting in Cairo was held in reference to the proposed construction of wastewater treatment plants in Ismailia and Port Said

as well as the proposed project in Suez City. Participants were invited to voice their concerns, questions, and comments regarding technical and environmental aspects of the planned wastewater treatment plant. Participants were further invited to submit comments in writing to Construction Management Consultants (CMC) by 1 March. This scoping report summarizes oral and written comments received for the Suez project EA. A list of attendees at the scoping meetings in Cairo and Suez City is attached.

PROJECT DESCRIPTION

Design Parameters

The Suez City wastewater treatment plant will be built to meet a projected year-2005 service population, which is expected to constitute 86 percent of the total urban population. The design flow rate for a plant is based on the current population and per capita water consumption for all uses--household, commercial, and industrial--plus the projected population growth times the expected usage rate. The planned capacity for the plant assumes that infiltration will be reduced for newly built areas. The year-2005 design flow for Suez City is 130,000 cubic meters per day.

Plant Location

Suez City's new wastewater treatment facility will be on the west shore of the Bay approximately 5 km southwest from the existing wastewater treatment facility next to the new power station. Effluent will be discharged into Suez Bay via either the Al Saal Drain or via an outfall-diffuser system extending into the Bay. The precise location and means of discharge will be determined in the final engineering design. A sludge disposal site has been tentatively identified at the west end of the site.

Aerated Lagoon Treatment Method

After screening and grit removal, the wastewater will flow through aerated and facultative lagoons, which are agitated to provide oxygen, and on to a polishing pond, where treatment continues. The bulk of the solids settle out in the facultative lagoons. Sludge handling is simplified because the sludge is partially stabilized in the lagoons and requires removal as infrequently as every 6 months to 2 years. Collected sludge will be dried in sludge drying lagoons, and then stockpiled at the plant for up to 90 days until disposal. As long as the plant is operating properly, its treated effluent will meet Egypt's Law 48 quality standards for BOD and TSS.

ENVIRONMENTAL CONSIDERATIONS

In 1989, during preparation of the Alternative Treatment Study, USAID requested a preliminary environmental review of the project. As a result, the following issues were identified for analysis in the EA.

Effluent Quality and Point of Discharge

Suez City's effluent will be discharged into Suez Bay, either directly or via the Al Saal Drain. Although treatment will greatly reduce the BOD, it will not eliminate it, and effluent nutrient levels will only be partially reduced. Determining the effects on water quality for the discharge alternatives will be an important part of the EA process. Location of the discharge point will be based on consideration of impacts on nearby seawater intakes at the power plant, fisheries research facility, oil refineries, and other shore-based facilities.

Effluent Reuse

Although the plant's preliminary design does not provide for reuse of the treated effluent for agriculture and aquaculture, the planned treatment method and means of effluent discharge do not preclude this as a future possibility. However, such future reuse entails a number of human health issues, which will be fully considered in the EA. High total dissolved solids content of the effluent in Suez may limit reuse in agriculture.

Sludge Disposal

The design now calls for sludge disposal primarily by on-site land disposal at a dedicated site on the west end of the proposed wastewater treatment plant site. The EA will explore the suitability of sludge use for agriculture subject to conditions imposed by public health and soil contamination concerns.

Public Health and Safety

Pathogens remaining in the effluent and sludge are important environmental concerns. Chlorination of the effluent may be required to significantly reduce the levels of pathogens in the effluent. The chlorine itself poses a threat to fish and other aquatic organisms and may need to be removed if it is deemed to be an environmental threat. Chlorine is in short supply and expensive in Egypt, and therefore may not be a reliable treatment method. The necessity and desirability of chlorination will be appraised in the EA.

Fly and mosquito breeding in wastewater standing at the treatment plant represents another possible disease transmission threat. The extent of the threat will be reviewed and environmentally sound methods of mitigating it identified.

210

Groundwater

Suez City has a relatively high groundwater table, both at the plant sites and beneath the collection system. The EA will address the potential for wastewater contamination of groundwater.

Noise, Traffic, Odors, and Other Nuisances

The proposed wastewater plant is a large capital project, occupying over 900 feddans that unavoidably will produce noise, traffic, odors, and other nuisances--both during construction and normal operation. An aspect of the EA will be fully cataloging these problems and identifying ways of mitigating them.

Effects on Aquatic and Wildlife Communities

The biotic communities of the Suez Canal region, as with its human communities, should greatly benefit from the proposed new wastewater treatment plant. Reducing the BOD, nutrients, and pathogens now flowing from Suez City will result in healthier aquatic communities in Suez Bay. Urban wastewater is only one of several sources of pollution now flowing into the Bay. The EA will endeavor to put the benefits accruing from improved wastewater treatment to Suez Bay and its associated natural communities in the context of water quality in Suez Bay.

COMMENTS RECEIVED

Cairo Scoping Meeting

Several participants at the Cairo scoping meeting offered comments germane to the scope of the EA. The following is a brief summary of these comments.

- Agricultural reuse of effluent and sludge. Several commentors and lively discussion focused on the desirability of reusing the wastewater and sludge for agriculture.

- Chlorination. Concern was expressed regarding chlorination of the effluent and its effect on fisheries.

- Parasites. Potentially high rates of infestation by the nematode *Ascaris* in the population, the resistance of eggs of this parasite to wastewater treatment, and implications for human health were noted.

- Disinfection. A question was raised regarding potential use of ozonation as an alternative to disinfection by chlorination.

211

- Reduction in fecal coliform. Interest was expressed in the rate of natural die-off of fecal coliform bacteria in the receiving water.

- Heavy metals. A question was raised about the levels of heavy metals in the sewage.

- Alternatives considered. Several commentors expressed an interest in alternative treatment methods that had been considered and the reasons for their rejection as the preferred alternative.

- Algae in treatment lagoons. A question was raised regarding algae blooms in the treatment lagoons, how these would be managed, and their effects on plant operation and the environment.

- Nutrient loading in Suez Bay. It was noted that if algal levels in Suez Bay increased because of nutrient loading, then adverse effects could result for the nearby power plant seawater intake.

- Ecological integrity of Suez Canal region. Concern was expressed regarding impacts of the proposed project on ecological functioning of the Suez Canal system and natural barriers to migration of species between the Red and Mediterranean Seas.

- Assimilative capacity of Suez Bay. Concern was expressed regarding the assimilative capacity of Suez Bay for both municipal and industrial wastes.

These comments and concerns will be considered and addressed by the EA. In addition to these comments germane to the EA, several comments and questions were raised regarding the treatment process and the EA process itself.

Suez Scoping Meeting

Several participants at the Suez scoping meeting offered comments germane to the scope of the EA. The following is a brief summary of these comments.

- Reuse of effluent. Several commentors expressed concern regarding the desirability of using effluent for agriculture. A question was raised about the effects of using saline effluent in desert reclamation. One participant asked whether the currently high salt content of the effluent could be reduced by additional treatment.

- Health risks. A question was raised regarding the health risk associated with operation and maintenance of a plant with the proposed treatment process.

212'

- Impact on tourism development. Concern was raised regarding effects of outfall discharge on tourism facilities.

- Future industrial development. A comment regarding the construction schedule and its impact on industrial expansion in the area raised the possibility of future inflow and treatment of industrial wastes at the site.

- Field study design. Information was requested on location of sampling stations and protocols.

- Discharge from ships in Suez Bay. A question was raised about the prohibition of discharge from ships in Suez Bay and whether enforcement of regulations occurred.

These comments and concerns will be considered and addressed by the EA. In addition to these comments germane to the EA, several comments and questions were raised regarding the treatment process and the EA process itself.

Written Comments

Written comments were received at the Suez scoping meeting, but some of these were directed at the projects in Ismailia and Port Said. These comments are incorporated in scoping reports for the respective projects. Written comments germane to the Suez project include:

- concerns about oil pollution in Suez Bay,

- interest in expected effluent quality, and

- energy consumption and costs associated with operation and maintenance.

These matters will be addressed in the EA.

Summary

Based on preliminary environmental review by the project team and questions and comments received at the scoping meetings for the Suez project, the following appear to be issues of primary concern:

- the expected impacts of the proposed discharge on water quality of Suez Bay;

- location of the outfall in Suez Bay and its impacts on seawater intakes at the nearby fisheries research and power plant facilities;

- impacts of the proposed discharge on plans for tourism development in Suez Bay;
- potential use of the effluent for agriculture and aquaculture;
- public health risks associated with effluent discharge and reuse;
- public health risks associated with re-use of sludge; and
- alternatives considered and the basis for their rejection as the preferred alternative.

Work Plan

A tentative outline for the Suez EA is attached. The issues of primary concern will be addressed in appropriate detail in the EA.

Water quality in Suez Bay will be evaluated with data collected during development of the Master Plan and during field studies by the project team in July and December 1989. Data from current meters moored in the nearshore area will improve knowledge of circulation patterns and help evaluate outfall locations. Indicators of sewage sludge deposits in the nearshore zone will be examined to further refine understanding of long-term nearshore circulation. Water quality data collected in 1989 will be used in water quality modeling efforts to evaluate impact of wastewater discharge on Suez Bay.

Development plans for the Suez Bay area will be reviewed to evaluate compatibility of land use plans with construction and operation of the proposed treatment plant facilities.

Quality of the effluent and its suitability for agriculture or aquaculture use will be described. Factors to be considered in re-use of the effluent will be briefly described; this analysis will facilitate future master planning effort for eventual expansion or upgrading of the proposed facility. In particular, quality of effluent and sludge with respect to bacteria and pathogens will be described, and implications for public health assessed.

The EA will briefly described alternatives that were considered and rejected in the planning and preliminary design stages, and explain the reasons for their rejection as the preferred alternative.

LIST OF ATTENDEES

Cairo Scoping Meeting - 8 February 1990

NAME	POSITION
Mr. Mahmoud Abd El Haleem Abdel Aal	Chairman of NOPWASD
Mr. Aly Hussein Aly	NOPWASD
Mr. Ahmed Hassan Khodeir	NOPWASD
Mr. Hossam El Deen Mohamed	NOPWASD
Ms. Samira Nicola	NOPWASD
Ms. Howaida Ennany	NOPWASD
Ms. Hala Abd El Kader Hassan	NOPWASD
Mr. Nabil Saleh	NOPWASD
Mr. Mohamed Negm El Deen	NOPWASD
Mr. Mohamed Ahmed Abd El Salam	Head of Ismailia City Council
Mr. Maher Faris	Director of Ismailia Sanitary Drainage
Ms. Marcelle Fakhry	General Organization for Reconstruction and Agricultural Development Projects
Mr. Ikhlas Gamal El Deen Mohamed	Center of Environment Health in Imbaba
Mr. Mohamed Kotb Naddar	Ministry of Public Works and Water Resources
Mr. Adel El Zoghbi	Deputy Minister for Foreign Financing (Ministry of Housing)

215

NAME	POSITION
Mr. Abdel Aziz El Basiouni	Suez Canal Authority
Ms. Samaa El Kassaby	STC
Mr. Abd El Salam Awad	Head of the Central Dept for Utilities
Mr. El Sayih Hiragy Hassan	Sanitary Drainage - Suez
Mr. Makram Milad	Director of Wildlife Preservation
Mr. Gameel Atta	Department of Wildlife Preservation
Mr. Mostafa Ahmed Mahmoud	Department of Wildlife Preservation - Giza Zoo
Mr. Mohamed Farouk Badawi	Environmental Affairs Agency
Mr. Hamed Badawi	Atomic Energy Authority
Mr. Ahmed Hassan Azzam	Atomic Energy Authority
Ms. Samar Karam Wissa	General Org. for Water Resources
Mr. Mohamed Elwan	General Org. for Development of Fish Resources
Mr. Hozayyen El Diwany	National Research Center
Mr. Hammam El Abd	National Research Center
Mr. Mohamed Ibrahim	Environmental Affairs Agency
Mr. Fathi Haikal	Food Provisions Sector
Mr. Saad Hassan	Food Provisions Sector

NAME	POSITION
Mr. Youssef Mahmoud Shideed	General Authority for Urban Planning Regional Project
Mr. Atef Mohamed Serour	General Authority for Urban Planning Regional Project
Mr. Mohamed Abd El Fattah El Kassas	Faculty of Science - Cairo University
Mr. Atef Diab	Instructor in the Faculty of Science (Suez Canal Univ.)
Mr. Magdi Mohsen Bahgat	Assistant Instructor at the Suez Canal Univ.
Mr. Ahmed Hamza	Alexandria University
Ms. Samia Galal Saad	Higher Institute of Public Health -Alex.
Mr. Mahmoud El Hewagy	Environmental Institute - Ein Shams Univ.
Mr. Mohsen Tawfik	Dean of Environmental Institute - Ein Shams Univ.
Mr. Samir Ghabbour	Prof. at the African Studies Inst. Cairo Univ.
Mr. Moustafa Fouda	Assoc. Prof. - Faculty of Science (El Azhar Univ.)
Mr. Paul Thorn	USAID
Mr. Michael Gould	USAID
Mr. John Saccheri	USAID
Mr. Ken Lue Phang	USAID
Mr. Medhat Wissa	USAID

21

NAME	POSITION
Mr. M.A. Feldt	USAID

Suez Scoping Meeting - 11 February 1990

NAME	POSITION
H.E. Gen. Tahseen Shannan	The Governor of Suez
Mr. Mohamed Negm El Deen	NOPWASD
Mr. Samira Nicola	NOPWASD
Mr. Mohamed Abd El Aziz Ahmed	Deputy of Housing and Utilities Dept - Suez
Mr. El Sayih Hiragy Hassan	Head of Suez Sanitary Drainage
Mr. Mohamed Hosni Abd El Maksoud	Suez Agricultural Dept
Mr. Selim Amer	Dept of Health Affairs
Mr. Taha Abou Shousha	General Director of Health Affairs
Mr. Hassan	Environmental Affairs Agency
Mr. President the Local Council	Director of Authority for Fish Resources
Mr. Yehia Salama	General Information Authority - Suez Center
Mr. Hossan Borai	Public Relations in the Governorate (Information)
Mr. Abd El Aziz El Basiouni	Manager of General Works Dept - SCA

NAME	POSITION
Mr. El Sayed Abd El Shafi	Egyptian Contracting Co (Ex. Mokhtar Ibrahim)
Mr. Abdallah El Haddad	Director of Governorate's Public Relations
Mr. Gharieb Gohar Gohar	Suez Information Center
Mr. Magdi Mohsen Bahgat	Assistant Instructor - Faculty of Science, Suez Canal Univ.
Mr. John Saccheri	USAID
Mr. Jim Gallup	USAID/Washington
Mr. Medhat Wissa	USAID

APPENDIX B
CANAL CITIES TECHNICAL REPORT:
WATER QUALITY ANALYSES - SUEZ

CANAL CITIES PROJECT TECHNICAL REPORT
WATER QUALITY ANALYSES - SUEZ

1.0 INTRODUCTION

1.1 Background

Preliminary engineering designs are being conducted by Construction Management Consultants (CMC) for wastewater treatment plants for the Canal Cities Project, funded in part by the United States Agency for International Development (USAID). Egypt's National Organization for Potable Water Supply and Sanitary Drainage (NOPWASD), in association with USAID, is proposing to build one of the new sewage treatment plants for the city of Suez.

Suez, a city of approximately 327,000 people (1986 census data), is located on the northern shore of Suez Bay, which in turn is located at, the northern tip of the Gulf of Suez. Suez is an industrial city with oil refineries and related petroleum infrastructure. Located at the southern terminus of the Suez Canal, it has extensive port and harbor facilities and is the seat of the Suez Governorate. Suez Bay is a major anchorage for ships waiting to pass through the Suez Canal.

The Suez Wastewater Facilities Master Plan (Pirnie-Harris International 1979) recommended that an oxidation ditch process would be the most appropriate wastewater treatment system for Suez. The Master Plan also evaluated alternative wastewater disposal options. These disposal options included: discharging to Suez Bay, Gulf of Suez, Suez Canal, or Suez Creek; wastewater reclamation for irrigation, aquaculture, or industrial reuse purposes; and evaporation and subsoil disposal methods.

Wastewater reclamation and reuse alternatives for Suez were not considered feasible by the Master Plan, primarily due to the wastewater's high total dissolved solids content. Evaporation and subsoil methods were also judged not feasible due to high groundwater levels and the unavailability of large tracts of land within a reasonable distance of the population center. Disposal to Suez Creek or the Suez Canal would have required a very high level of treatment; the latter would possibly have had impacts on Great Bitter Lake due to the predominantly northward flow in this part of the Suez Canal during most of the year.

221

In order to assess the ability of Suez Bay and the Gulf of Suez to assimilate the wastewater discharge, the Master Plan included a comprehensive oceanographic and water sampling program, and a subsequent water quality modeling effort (Marine Environmental Services, Inc. 1979). This study recommended that secondary treatment with nitrification would be necessary for a wastewater discharge to the Suez Bay due to poor circulation within the bay area. Alternatively, a discharge of primary-treated wastewater to the Gulf of Suez would also be acceptable and, in fact, have a smaller water quality impact than the Suez Bay option.

During preparation of the Project Paper for Phase II of the project, USAID recommended rapid infiltration land disposal of the wastewater effluent. This recommendation eliminated the need for discharge to the marine environment.

The CMC was authorized by USAID/Cairo to conduct studies of alternate wastewater treatment facilities for Suez (Task Order No. 9). NOPWASD and USAID tentatively agreed that an aerated lagoon treatment method should be used by the proposed Suez wastewater treatment plant, basing the decision on considerations of cost, simplicity of operation, land requirements, and effluent quality.

1.2 Objectives

The CMC's proposed wastewater treatment facilities would produce a Law 48 effluent that is superior to primary treatment but would not meet the requirements recommended in the Master Plan (Pirnie-Harris International 1979). In addition, projected flows for this project have been reduced considerably from the earlier study. As the Alternative Treatment Study was developed by CMC between February and April 1989, a series of questions were raised with reference to environmental implications of a discharge via outfall in Suez Bay. A decision was made to re-evaluate effluent disposal to Suez Bay.

The purpose of this study is to compare the impact of a Law 48 effluent and a primary effluent in terms of their water quality effects on Suez Bay. The objectives of the analysis are to help answer the following basic questions:

- Will the reduction in flow volume and improvement in treatment (Law 48 standards for 5-day biochemical oxygen demand and total suspended solids) result in acceptable water quality effects from discharge to Suez Bay?

- What are the comparative advantages of 5, 10, or 15-m deep submarine outfalls or discharge to the bay via open drain, as is the present practice?

1.3 Approach

The starting point of this analysis was the series of studies and reports prepared by Pirnie-Harris International (1979) in connection with preparation of the Wastewater Facilities Master Plan for Suez. These reports provide an analysis of receiving water body assimilative capacity based on data collected in 1979 or available at that time from other sources.

Significant changes may well have occurred in the water quality of Suez Bay since 1979. Reconstruction of the city and its petroleum industry facilities, deepening and widening of the Suez Canal, and potential increases in shipping traffic may have modified pollutant loadings or circulation patterns in the bay. As a consequence, CMC was authorized by USAID/Cairo in June 1989 to conduct a limited program of field sampling of key water quality parameters. This program was carried out in July 1989 and provided additional data for evaluating pertinent water quality issues. A possible discharge to the Gulf of Suez was also examined, but at the level of a general survey only. More definitive effort was judged unnecessary because the Gulf of Suez was not likely to be a preferred alternative because the pipe distances associated with a marine outfall to the Gulf are appreciably greater than those for an outfall to the bay, and the Gulf's value as a fishery is significant.

The data generated by the July 1989 field study, along with other available data, were analyzed through a combination of simple desk-top analysis techniques and more sophisticated computer simulation models. The July 1989 data were incorporated into a preliminary draft environmental review of the Canal Cities project. In that environmental review, the analysis focused on the water quality impact of a discharge of effluent which would meet the requirements of Egyptian Law 48. The Law 48 effluent would contain no more than 50 mg/l total suspended solids (TSS) and 60 mg/l 5-day biochemical oxygen demand (BOD_5).

The July 1989 field data indicated that a Law 48 discharge to Suez Bay would have little adverse effect on water quality. The modeling effort examined an outfall at a depth of 15 m approximately 2.2 km from shore, which would provide sufficient dispersion and dilution of the effluent. During presentation of the results of the preliminary environmental review to the CMC and USAID, concerns were raised regarding the policy implications of an outfall to Suez Bay. It appeared that discharge to the existing El Saal storm drain or to a new surface drain should also be considered. It was decided that data from the nearshore zone should be collected and analyzed to refine the analysis. Specifically, the flow regime near both the present El Saal Drain discharge site and possible submarine outfall sites nearer shore was insufficiently well known to confidently predict the fate and effects of the discharge to Suez Bay. A current monitoring program, using both moored and profiling current meters, was therefore conducted; the current measurements were augmented with direct measurement and sampling for water chemistry.

The additional sampling program focused on nearshore physical processes near the El Saal Drain. The key questions to be answered were:

- What are the current patterns in the nearshore zone around El Saal Drain?
- What are the water quality impacts of nearshore discharge?

Additional water quality field studies were conducted in November-December 1989 to address these two questions.

2.0 METHODS

2.1 Field Investigations

2.1.1 July Field Studies

Water quality samples were collected in Suez Bay 20-22 July 1989. Positioning of the stations (Figure 1) was established with hand-held compass bearings to permanent buoys or landmarks. Grab samples of effluent in El Saal Drain were taken at the primary effluent discharge, the effluent bypass, and in the main drain. Additional samples were taken at the Coastal Road bridge on 28 August 1989.

Salinity, temperature, pH, dissolved oxygen, and water clarity were measured in the field at varying depths. A YSI Model 51B temperature/oxygen meter was used throughout the sampling program. Water clarity was determined with a standard 20-cm diameter Secchi disk. Salinity and pH measurements were made with equipment on loan from the Ministry of Health's Environmental and Occupational Health Center Laboratory in Cairo (Embaba District).

2.1.2 November Field Studies

Field studies in Suez Bay were carried out between 18 November and 14 December 1989. The field effort was designed to collect additional data on water current and circulation patterns, physical and chemical characteristics of the water column, seafloor sediment microbiology, and flow volumes and constituents presently discharged into Suez Bay via the El Saal Drain. The sediment microbiology task was designed to aid in determining the predominant flow pattern of the wastewater effluent by examining the distribution of persistent amoebic cysts in marine sediments.

Six primary stations (Stations 1 through 6) formed the core of the nearshore sampling program; ocean current and CTD (conductivity/salinity, temperature, density)

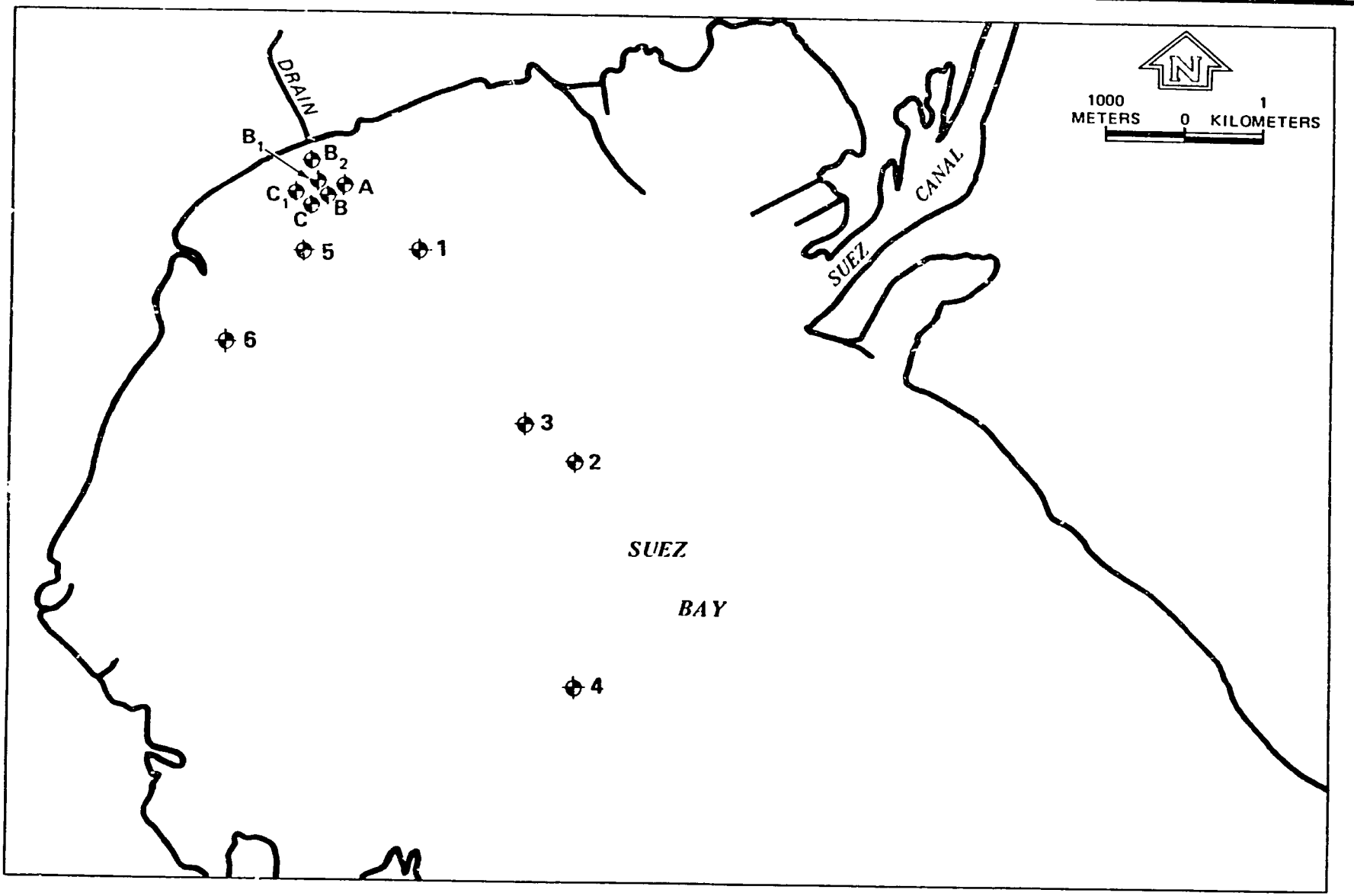


FIGURE 1
SUEZ BAY SAMPLING STATIONS, July 1989

Dames & Moore

profiles were collected at four additional stations (7 through 10) located in other parts of Suez Bay (Figure 2). Two stations of opportunity (Stations A and B) were profiled once each to obtain data on the flow and water characteristics of the power plant and refinery discharges. On two occasions, 2-3 December and 7-8 December, the six primary stations were occupied every 6 hours over a 24-hour tide cycle.

Bottom sediments and surface seawater were collected at 21 stations (Stations 1-6, 20-34) distributed throughout the eastern half of the bay for sediment microbiology and fecal coliform determinations. (The number series of Stations 11-19 was reserved in case field observations suggested a special sampling regime; but this series was not used.)

Finally, flow was measured and water samples were collected from the El Saal Drain at the Coastal Road bridge (500 m upstream from its mouth).

2.1.2.1 Oceanography

Oceanographic studies comprised direct measurement of current velocities with moored and profiling current meters, tracking of current drogues, vertical profiles of seawater characteristics (conductivity, temperature, and dissolved oxygen), and ancillary observations and measurements (wind velocities, sea states, and visual characteristics of water and sediments).

Currents were measured using two self-recording current meters that remained submerged for an approximate 1-month period, and one profiling current meter with which repetitive vertical profiles of current speed and direction were collected. Three electromagnetic current meters (Model S4, manufactured by InterOcean Systems, Inc.) were used during the field effort; two were placed on taut-moored arrays, and one was used for vertical profiling of currents. The taut-moored arrays were located near the existing and proposed discharge sites; the first (Station 5) was located in 5 m of water approximately 1400 m offshore of the El Saal Drain, while the other (Station 6) was deployed in 11 m of water located approximately 2100 m offshore of the proposed wastewater treatment plant site on the western shore of Suez Bay.

The in-situ meters were programmed to: a) measure north and east flow components every 0.5 seconds for one out of every five minutes, b) average those 120 readings, and c) write the average values to memory every 5 minutes. Seawater temperature was also recorded once every 5 minutes. The contents of the memory were transferred to a microcomputer after retrieval of the current meters, and were subsequently resolved into current speeds and directions. Unfortunately, a microprocessor malfunction affected the direction calibration of the current meter moored at Station 6; those data were not recoverable.

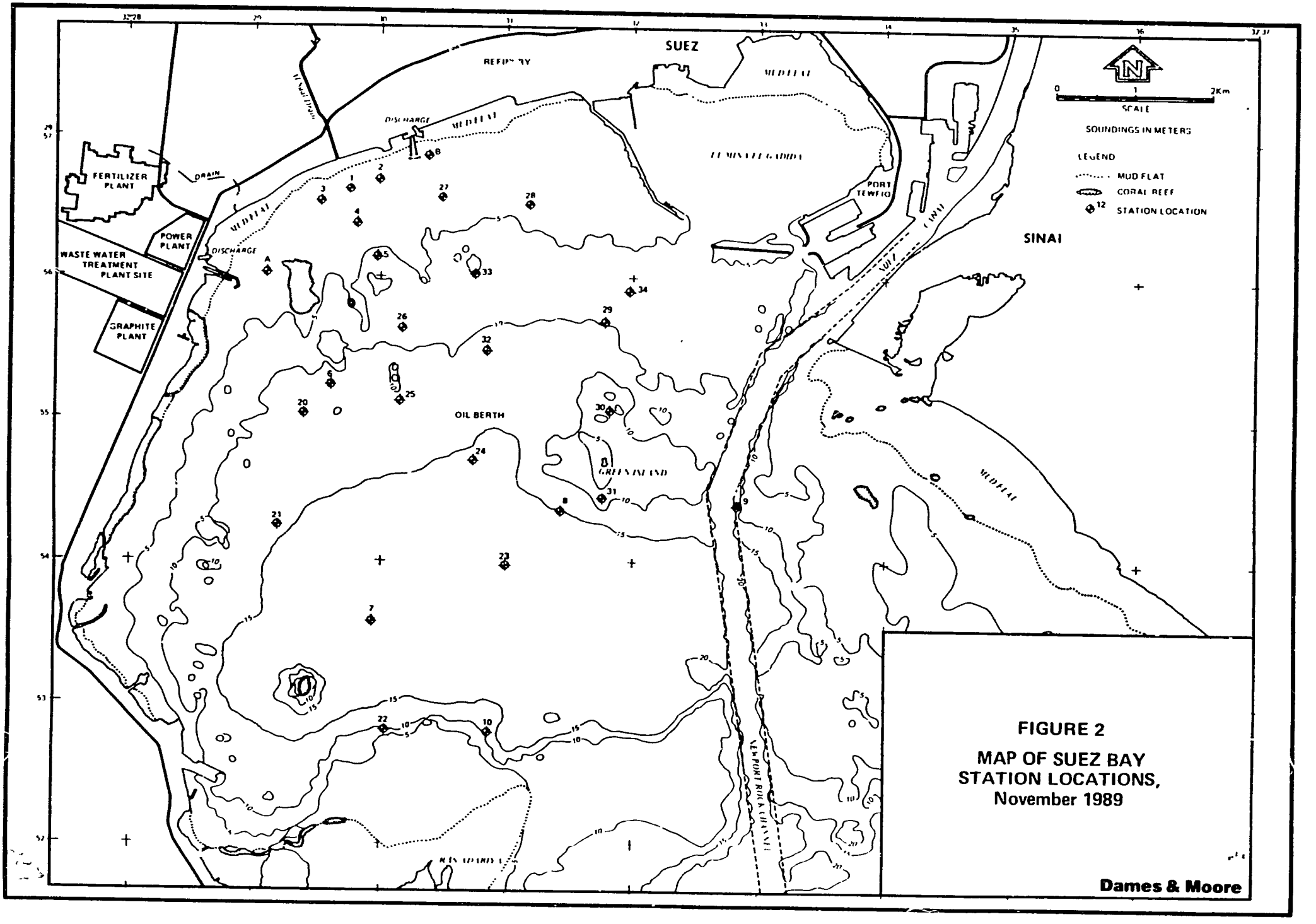


FIGURE 2

MAP OF SUEZ BAY
STATION LOCATIONS,
November 1989

Dames & Moore

The current meter used for vertical profiling was equipped with a depth sensor and provided depth-dependent flow data. It was programmed to measure seawater pressure and north and east flow components every 0.5 seconds and to record those values to solid state memory without averaging. The contents of the memory were transferred to microcomputer data files in the field immediately after each profile was taken. The InterOcean S4 current meters used have both resolution and threshold equal to 0.2 cm/sec, and an accuracy of 2% of the reading $\pm$ 1 cm/sec.

Current drogues were deployed at Station 1 on 6 December and at Station 6 on 9 December. They were window-shade drogues constructed of bamboo and a 1-m^2 panel of plastic sheeting extending from the air-water interface down to a depth of 1 m.

Vertical profiles of seawater conductivity and temperature versus pressure were measured using an internally-recording CTD (a SEACAT Model SBE 19 CTD, manufactured by Sea-Bird Electronics). Data were acquired twice per second as the instrument was lowered and were written to solid-state memory; these were transferred to a microcomputer in the field after each CTD cast. Each CTD profile was therefore derived from a few hundred to several hundred discreet temperature, conductivity, and pressure measurements, which were averaged over 0.1 m depth intervals. Seawater salinity and density were computed from the electrical conductivity, temperature, and pressure values using conversion programs supplied by the manufacturer.

Vertical profiles of dissolved oxygen (DO) concentration were measured using a Model 57 DO meter manufactured by Yellow Springs Instruments, Inc. The DO meter was not calibrated until the meter had warmed up for at least 1 hr. Calibration was checked periodically throughout the day. The sensor and mechanical stirrer were lowered over the side of the vessel on a marked conducting cable; the oxygen values, corrected for temperature and salinity, were recorded manually. The sensor membrane was changed prior to each day's use, and more often when it was lowered through surface oil layers (as commonly occurred).

Water clarity was determined during daylight hours using a standard 20-cm Secchi disk, which was lowered into the water column until it was no longer visible from the surface.

2.1.2.2 Meteorology

A recording weather station, consisting of wind speed and direction and air temperature sensors, was set up on the roof of the Suez Canal Authority administration building in Port Tewfiq (atop the observation room). The instrument, a Meteorology Research Inc. Model 1071 Mechanical Weather Station, recorded measurements in analog form on a paper strip chart. The wind and air temperature data recorded on the chart were subsequently digitized for analysis and plotting.

2.1.2.3 Water Chemistry

Samples of surficial seawater, taken from the upper 0.25 m of the water column, were collected on several occasions throughout the 1-month field survey. These were routinely collected offshore at Stations 1 through 6, and from the El Saal Drain at the Coastal Road bridge. Water samples for nutrient analyses were stored in clean, unused plastic containers, and those for fecal coliform were stored in sterile glass bottles; all samples were immediately stored on ice and transferred to the analytical laboratory in Cairo within 24 hours of collection. Although conversion of particulate nutrient fractions to dissolved fractions is possible during storage, the effect is not likely to be significant because the samples were stored in the dark on ice.

2.1.2.4 Sediment Microbiology

Bottom sediment samples from Suez Bay were collected from 21 stations (Stations 1-6, 20-34) on 1-2 December 1989 using a hand-held Eckman grab. Subsamples were stored in sterile plastic bags for transport to the microbiology laboratory in the United States. Details of the field and laboratory methodology are provided in Dames & Moore (1990).

2.2 Laboratory Analyses

2.2.1 July Field Studies

Water samples were collected from surface water and placed in 5-liter plastic bottles. Plastic bottles were provided by the Ministry of Health's Environmental and Occupational Health Center Laboratory in Embaba (Cairo), which also conducted the laboratory analyses. All sample bottles were acid washed and double rinsed in distilled water in the laboratory. Sample containers were double-rinsed in the field with sample water prior to filling. Sediment samples were collected with a hand-held Eckman grab and placed in 1-liter sample bottles, which were rinsed as above.

Water samples were analyzed for chlorophyll a, BOD_5, chemical oxygen demand (COD), total phosphate ion as phosphorus (TP), ortho-phosphate, nitrate, ammonia, total Kjeldahl nitrogen (TKN), oil and grease, TSS, sulfate ion, chloride, and hardness. All water and sediment samples were immediately stored in the dark on ice and shipped at the end of the day to the laboratory in Cairo. Techniques of analysis were according to American Water Works Association (1985) Standard Methods for the Examination of Water and Wastewater.

In July 1989, samples for fecal coliform bacteria counts were collected and immediately filtered with a hand vacuum pump and filter kit. Following filtration,

samples were placed in a portable incubator for storage and transport. Fecal coliform counts were obtained using the membrane filter technique.

2.2.2 November Field Studies

Water samples were collected at each station and were analyzed for: BOD_5, COD, total phosphorus (TP), ortho-phosphate (PO_4), TKN, ammonia (NH_3), nitrate (NO_3), silica, fecal coliform bacteria, and chlorophyll a. In November-December 1989, samples for fecal coliform bacteria counts were collected directly in a sterilized glass BOD jar from surface water and immediately placed on ice for shipment. Water samples were collected in newly purchased 1-liter plastic bottles that were double-rinsed in the field with sample water prior to filling. Water samples were stored on ice and delivered to the Ministry of Health's Environmental Health Center Laboratory in Cairo the morning after each survey.

2.3 Water Quality Modeling

2.3.1 PLUME

The initial dilution and dispersion of wastewater from the proposed submerged outfall were estimated by using a variant of the PLUME model developed by the U.S. Environmental Protection Agency (Muellenhoff et al. 1985). Because ambient current and density profiles were measured nearby during the November-December 1989 field effort, the variant UDKHDEN was applicable and was used; UDKHDEN allows modeling of multiple-port diffusers into specified density and flow fields.

Input parameters for UDKHDEN are:

- effluent density (or temperature and salinity, from which the programs calculates density) and total effluent flow;
- the number, depth, diameter, spacing, and discharge angle of diffuser ports;
- the ambient current speed profile and the horizontal angle of current flow with the diffuser alignment; and
- depth-dependent salinity and temperature profile (or density profiles).

Output parameters include the three-dimensional extent of the plume at various time steps, the dilution of the effluent at those same time steps, and the time required for the plume to reach the water surface.

The PLUME model was applied to oceanographic data collected in November-December to proposed outfalls located in 5 and 10 m of water.

2.3.2 WASP4

Prediction of water quality impacts resulting from the two alternative proposed discharge schemes (submarine outfall and open drain) were investigated using the WASP4 model developed by the U. S. Environmental Protection Agency (described in detail by Ambrose et al., 1988). The model comprises two major components, a hydrodynamic program (DYNHYD4) that simulates the transport of receiving waters, and a water quality element (WASP4) that predicts the movement and interaction of pollutants within the system.

The hydrodynamic component of WASP4 (DYNHYD4) solves one-dimensional equations of motion and continuity, and can provide input of flow fields into WASP4. One of several underlying assumptions in the model is that water flows are one-dimensional, i.e., invariant with depth. Because we have found that the flow regime near El Saal Drain varies as a function of depth (Section 3.3.2.1), the hydrodynamic model was not used to compute the advective fields input into WASP4. Rather, flow fields in the water quality model were directly incorporated in the model, using measured and extrapolated current data.

WASP4 is a model which provides conservation of mass for a variety of water quality constituents. EUTRO4 is the WASP4 submodel that addresses conventional constituents such as BOD and nutrients. EUTRO4 was used in this evaluation.

WASP4 requires input data defining seven characteristics:

- o simulation and output control;
- o model segmentation;
- o advective and dispersive transport;
- o boundary concentrations;
- o point and diffuse source waste loads;
- o kinetic parameters, constants, and time functions; and
- o initial concentrations.

EUTRO4 describes BOD-DO interactions, nutrient mass balances, and nutrient uptake by phytoplankton. Settling is handled as are sediment interactions.

The WASP4 model was used to examine primary and Law 48 discharges at a 15-m deep outfall, using the July oceanographic data. The model was run again for the 5- and 10-m deep outfalls, using the November-December oceanographic data. The specific input data and the portions of WASP4 code used for the initial work are described in Dames & Moore (1990). (The WASP4 model was also used in the initial

work to examine water quality impacts on Great Bitter Lake.) The specific input data and the portions of WASP4 code used for the latter work will be described later in this report (Section 3.3.2).

2.3.3 Officer and Ryther

Officer and Ryther (1977) developed a waste oxidation model that provides a preliminary (screening level) evaluation of DO changes resulting from a wastewater discharge. The model is based on deoxygenation by BOD inputs and reaeration resulting from forces such as wind mixing and algae photosynthesis.

In the Officer and Ryther analysis, the existing waste dissolved oxygen deficit (WDOD) was computed from measured flows coming into Suez Bay from El Saal Drain. Wastewater flows and BOD_5 concentrations for the year 2005 were taken from the CMC Alternatives Treatment Study, and primary effluent loads were computed assuming that the primary effluent BOD_5 concentration was 210 mg/l.

3.0 RESULTS

3.1 Master Plan Findings

Suez Bay is a relatively shallow, elliptical body of water with a maximum depth of 20 m. The Suez Canal joins the bay on the northeast shore, and the bay is bordered on the south by the Gulf of Suez. A rock sill at a depth of 10 m separates the bay from the gulf. A channel has been dredged through the rock sill to a depth of about 17 m to enhance shipping access to the bay.

The flow pattern in the bay is greatly influenced by the shoreline configuration and the submarine topography. There are no significant freshwater inputs to the bay. The flow is circular within the bay, with the predominant mixing and water exchanges occurring with the Gulf of Suez. Pirnie-Harris International (1979) concluded that the general circulation pattern in the bay is counterclockwise and that the influence of the Suez Canal is minor. The circulation pattern is principally controlled by tidal forces, which are most active during the spring cycle. Wind forces also play a role in seasonal circulation patterns. As the tidal and net circulation pattern is seasonally variable and only a limited set of measurements were made in 1979 by Pirnie-Harris International, a complete picture of the bay's flow patterns is not presently available.

It has been estimated by Pirnie-Harris International (1979) that a parcel of fluid discharged from a wastewater outfall located on the northwestern shore of the bay would have an estimated residence time of 50 days, which is considerable. Water quality in the bay is generally good but polluted to varying degrees in localized areas

with untreated domestic wastewater, urban runoff, industrial wastes, and oil from either local refineries or oil tankers. The bay's capacity to accept wastewater flow is dependent on the following:

- the hydrodynamic characteristics and tidal exchange with the Gulf of Suez,
- the initial dilution and subsequent transport and decay of BOD, coliform bacteria, and nutrients;
- the existing benthic oxygen demand and oxygen reaeration rate; and
- the stimulation of phytoplankton growth and the potential for local or widespread eutrophication as a result.

Biological sampling performed in 1979 revealed moderate levels of diversity and activity. Phytoplankton sampling was dominated by 47 species of diatoms and 19 species of dinoflagellates. The filamentous blue-green alga Oscillatoria spp. was also sampled throughout the bay. Chlorophyll a at concentrations reported to be indicative of moderate "bloom" conditions were also present. Pirnie-Harris International (1979) concluded that the phytoplankton sampling indicated moderately eutrophic conditions symptomatic of a slightly polluted embayment that still maintains a healthy and relatively productive ecosystem.

The bay's zooplankton community was also found to be relatively diverse, consisting principally of copepods but also chaetognaths, appendicularians, doliolids, amphipods and small numbers of invertebrate larvae. Benthic fauna (worms, molluscs, echinoderms, and crustaceans that live in or on the mud bottom) were largely lacking within the bay, a surprising finding given the presence of a highly organic substrate that would normally support a dense benthic community. The investigators hypothesized that periodic anoxic conditions in the bay, perhaps occurring annually when thermal stratification is present, accounts for this impoverished benthic fauna.

Pirnie-Harris International (1979) identified DO as the critical water quality parameter for Suez Bay. Benthic oxygen demand is believed to be high in some areas and the reaeration rate limited due to the low tidal velocities. This finding resulted in establishment of 1.0 mg/l as the recommended maximum allowable oxygen depression due to a proposed wastewater discharge (Pirnie-Harris International 1979).

High DO concentrations were measured in January 1979 and varied between 4.7 and 6.4 mg/l. The saturation value for oxygen under the temperature and salinity conditions experienced at the time is approximately 7.4 mg/l. Higher values, between 6.8 and 8.0 mg/l were measured in March 1979.

It is important to note that very small differences in oxygen concentrations were noted in the DO depth profiles. These high values throughout the water column were reported to be due to the very shallow water and active vertical mixing. These values indicate that oxygen depression due to waste assimilation was not a problem in January or March 1979. It was assumed that oxygen levels would drop in summer due to warmer sea temperatures and water column stratification.

DO levels can be influenced by algal photosynthesis during daylight hours. Measurements of chlorophyll a in 1979 in the bay ranged between 0.61 and 4.95 ug/l, and averaged 2.0 ug/l.

Turbidity is an important parameter to consider in conjunction with chlorophyll and dissolved oxygen because light penetration influences the mass of phytoplankton that produces oxygen. Turbidity measurements averaged 1.0 Nephelometric Turbidity Units (NTU) in the bay area in 1979, and average Secchi disk extinction depths were approximately 3.2 m. There was apparently some dredging occurring in the eastern part of the Gulf at the time where smaller extinction depths were measured. This activity could have influenced the reading in the bay also.

Ammonia-nitrogen concentrations in 1979 in the bay ranged up to 1.68 mg/l, with the majority of readings below detection limits. Nitrate concentrations ranged up to 0.64 mg/l, again with the majority of readings below detection limits. Nitrite concentrations were low, as to be expected.

Ortho-phosphorus was detected in 1979 only twice (at 0.004 and 0.010 mg/l P) in 43 samples. TP, however, ranged up to 0.070 mg/l with an average of approximately 0.026 mg/l.

Total coliform counts in 1979 were low at all stations, ranging between 2 and 1000 most probable number per 100 milliliters (MPN/100 ml) and averaging 100 MPN/100 ml. Fecal coliform measurements never exceeded 50 MPN/100 ml, and usually were not detectable.

Pirnie-Harris International (1979) assessed the impact of the projected wastewater loadings by performing a water quality modeling study using the computer code HAR03. Results of that study indicated that a high level of treatment would be necessary to prevent algal bloom conditions in the summer period. The approach used was to identify a maximum acceptable level of DO depression in the bay (1.0 mg/l), and the required level of treatment was then back-calculated. It was assumed that excessive levels of algae growth would occur if nitrogen concentrations exceeded an assumed critical level of 0.25 mg/l. While this approach seems reasonable, there are a number of problems associated with it. First, it assumes that the oxygen demands and sources are accurately known. Second, while the bay has a maximum assimilative capacity, the loading is variable; thus, an overly conservative estimate of the wastewater loadings will result in higher levels of treatment. Third, the 1979 analysis assumed that

234

excessive levels of algae growth would take place if nitrogen concentrations exceeded 0.25 mg/l. In fact, 1989 nitrogen concentrations exceeded 0.25 mg/l without excessive chlorophyll a concentrations (Section 3.3.2.2).

3.2 Gulf of Suez

The Gulf of Suez, an arm of the Red Sea, is a relatively long body of water that extends in a southerly direction into the Red Sea. It contains maximum water depths of 40 m. The physical oceanography of the northern gulf was studied in 1979 by Pirnie-Harris International. The gulf is an open coastal environment with a moderate to strong circulation flow, in contrast to Suez Bay. Circulation patterns are driven by tides, currents, and wind, with the resulting circulation flow proceeding in a clockwise direction at the head of the gulf. Greater dilution than is possible in Suez Bay occurs due to greater water depths and more favorable circulation characteristics. The assimilative capacity of these waters was reported to be higher as well (Pirnie-Harris International 1979). Because of the greater level of mixing and dilution that occurs in the gulf, the water of the Gulf of Suez are not as sensitive to effluent discharges as Suez Bay (Pirnie-Harris International 1979).

Discharge of treated effluent from the proposed Suez wastewater treatment plant will obviously have a less severe impact on the Gulf of Suez than Suez Bay due to the greater flushing capacity of the Gulf of Suez. Hydrodynamic studies conducted for Pirnie-Harris International (1979) found ebb and flood tidal velocities in the range of 10 cm/sec, compared to 5 cm/sec in the bay, with average circulation velocities of 6 cm/sec in the gulf operating in a northeast clockwise direction. By contrast, circulation velocities in the bay were less than 4 cm/sec. Plume modeling of proposed gulf discharges in 1979 found greater mixing and dilution due to greater depths and the higher tidal and circulation velocities. The 1979 study concluded that the Gulf of Suez could sustain discharge of a primary treated effluent.

Very limited data are available on the marine ecology of the Gulf of Suez. Pirnie-Harris International (1979) carried out a limited program of sampling at a number of stations during January 1979, acknowledging that sampling at four closely-spaced locations at one time of year is hardly sufficient to describe the biological environment of so large and complex an area as the Gulf of Suez. The net phytoplankton population is essentially similar to that found in Suez Bay in species composition, but overall populations are less dense. Chlorophyll a concentrations are typical of those found in unpolluted coastal ocean waters. Zooplankton population densities were similar to those found in the bay, although species composition was quite different. Copepods (Oithona and other small copepods) represented a significant fraction of the population, around 25%, but other non-crustacean zooplankton were found in greater abundance than in Suez Bay.

Benthic fauna was low and highly variable in numbers of individuals, numbers of species, and total biomass. Polychaete worms dominated the samples, but bivalve mollusks, especially Tellina sp., Macrocallista sp. and Chione sp., were also present. Also found were ophiuroids and tanaid crustaceans. However, by comparison with other coastal marine ecosystems, the Gulf of Suez is relatively impoverished in benthic biomass, owing either to low productivity of the overlying waters or periodic anoxia and mortality (Pirnie-Harris International 1979) in deeper water.

The gulf maintains a productive fishery which is commercially exploited. More than 138 species of fish have been recorded in the Gulf of Suez. Those that are abundant and make up the bulk of commercial landings are: sardines, anchovies, mullet, and penaeid shrimp. These planktivorous species make up about 75% of commercial fish landings, while jacks, mackerel, tuna, sea bream, lizard fish, and other predator species are also taken from the gulf. The food chain that supports the gulf's commercial fishery appears to be short and almost exclusively plankton-based (Pirnie-Harris International 1979).

Although fishery stocks in the Red Sea are not as productive as other tropical marine environments, the great variety of species which exist have been exploited by local fishermen for centuries. Fishing activity in the Red Sea is concentrated in the Gulf of Suez because of its relative shallowness and smooth bottom, which makes it suitable for trawlers and seiners (Baldwin et al. 1988). It is also considered an underexploited fishery resource. In view of the importance of the gulf's fishery, the additional force main pipe and pumping distances associated with an outfall to the gulf as compared to the bay, and the analytical finding (Section 3.3) that discharge of a Law 48 effluent to Suez Bay will be environmentally acceptable in terms of its water quality impacts, there is no reason to further consider the Gulf of Suez as a receiving water body alternative at this time.

3.3 Suez Bay

3.3.1 July 1989 Findings

3.3.1.1 July Water Quality

A limited water quality sampling program in July 1989 was included as part of this water quality analysis. The July sampling period at Suez was relatively short; therefore, the amount of data collected was limited. However, the data provide a "snapshot" of the existing water quality in Suez Bay, allow an assessment of the impact of the untreated discharge to the bay since the 1979 study, and provide data from the summer period (when water quality conditions are likely to be their worst) which no previous studies have provided. The station locations for the July sampling program are shown in Figure 1.

The results of the July 1989 sampling effort are documented in Dames & Moore (1990). This section discusses and compares the findings of the 1989 and the 1979 sampling programs. It thus serves to characterize changes in ambient water quality conditions over the intervening time.

DO profiles were performed in July 1989 when water temperatures were approximately 26°C and the saturated dissolved oxygen level was about 6.0 mg/l. All DO measurements were high and fairly uniform with depth. Values ranged between 5.4 and 7.1 mg/l, with the lower value occurring in the sample nearest to the untreated sewage outfall. These data confirm that active vertical mixing is occurring, and DO depletions in bottom water are less likely than what had been previously anticipated.

Average station values for chlorophyll a were found to vary between 1.6 and 4.8 ug/l, with an average value of 2.9 ug/l. While these are somewhat higher than the 1979 values, it must be noted that the majority of the samples were collected near the El Saal Drain, which presently discharges effluent from the existing treatment plant. Values from stations near El Saal Drain ranged from 2.8 to 4.8 ug/l. The average of sampling locations in the bay proper is 2.0 ug/l, which is the same as the previous average observed in 1979. This chlorophyll concentration is considered relatively low and should not influence the DO levels significantly. Differences of 1.0 mg/l were typical between side-by-side light and dark BOD analyses. These data indicate that the system is in relative equilibrium, and that a sudden algal bloom beyond current levels is unlikely.

BOD values measured in July ranged between 3 mg/l in the middle of the bay to 16 mg/l in the nearshore area immediately out from the existing wastewater discharge point via the El Saal Drain. In spite of this latter value, minimal DO depression was observed.

In the July 1989 study, Secchi disk transparency depths ranged between 2.4 and 3.6 m at all locations, with the exception of the sampling stations directly out from the El Saal Drain, which were between 1.8 and 2.4 m.

Average ammonia-nitrogen values in July varied between 0.01 and 0.35 mg/l. There did not appear to be much correlation between station location and ammonia values. The highest value occurred at Station 4, the most seaward station, and the values were generally lower than those noted in 1979. Interestingly, the highest ammonia concentration reported by Pirnie-Harris International (1979) was 3.36 mg/l at a location just outside the bay area, close to Station 4 of the July study. The usual range for ammonia-nitrogen in sea water is between 0.001 and 0.05 mg/l (Johnston 1976). Similar patterns occur with nitrate-nitrogen and TKN values. Reported nitrate values ranged between 0.15 and 0.64 mg/l in the 1979 study, while in the July 1989 study values ranged between 0.05 and 0.17 mg/l. Typical nitrate concentrations in sea water have been reported in the range of 0.001 to 0.50 mg/l (Johnston 1976). In

231

general, the nitrogen values in July appear similar, or slightly improved, with respect to those measured in 1979.

In July average station values for ortho-phosphorus and TP ranged from 0.01 to 0.11 mg/l and 0.01 to 0.08 mg/l, respectively. The average ortho-phosphate concentration in the 1989 sampling was 0.01 mg/l, with an average TP concentration of 0.02 mg/l, similar to 1979 results. Both high values occurred at the same sampling location, near the El Saal Drain. The usual range of phosphorus in the open sea has been reported as 0.001 to 0.075 mg/l P, which is consistent with the findings (Johnston 1976).

In contrast to the other parameters which were similar between 1979 and July 1989, fecal coliform measurements were significantly higher in July, ranging between 500 and 1000 MPN/100 ml. The reason for the difference is not clear. The methods used for determining the counts appear similar, and samples were filtered on the survey vessel and immediately incubated for both studies. Some increase in coliform numbers was to be expected, as the recent sampling was concentrated more around the nearshore pollution from the El Saal Drain; however, counts in the middle of the bay also differed significantly between the 1979 and July 1989 surveys.

Shore and nearshore pollution of the bay is significant in the area of the El Saal Drain, the discharge point for the existing Suez wastewater treatment plant's untreated domestic wastewater. An oil sheen from onshore sources covers a large area near the drain outlet. Other oil pollution in the bay is significant and is visually apparent.

There is still very poor definition of other discharge points and pollutant loadings into the bay; for example, that from the oil refinery, fertilizer factory, and other drains. Although water quality in Suez Bay shows signs of oil pollution and pollution around the El Saal Drain from wastewater discharge, all available indications are that the bay is satisfactorily coping with the existing situation. In general, despite nearly 10 years of discharges of untreated wastewater into Suez Bay from the existing Suez wastewater treatment plant (WWTP), as well as pollution from other sources, water quality conditions as monitored in July 1989 are not markedly different from conditions measured in 1979. The only significant difference appears to be the increased degree of contamination by fecal coliform bacteria in the surface water throughout the bay.

The July 1989 study found that water quality conditions had not significantly changed from conditions observed in 1979 by Pirnie-Harris International. The summer 1989 water quality conditions were as follows:

- DO concentrations were near saturation throughout the water column at a number of stations within Suez Bay.

- Nutrient concentrations were somewhat elevated, however chlorophyll a levels were low, generally less than 10 ug/l.

- Fecal coliform concentrations in 1989 were higher than observed in 1979 and were generally in the range of 1000 organisms/100 ml.

- Wasteload allocation analysis indicated that Suez Bay could adequately assimilate BOD inputs; however, the eutrophication effects of increased nutrient loads were recommended as a subject for additional investigation.

3.3.1.2 July Water Quality Modeling

One of the water quality models used in the analysis of the July data is WASP4, which is far more comprehensive and sophisticated than the HAR03 code previously used by Pirnie-Harris International (1979). The WASP4 model was used to predict DO, nutrient, and phytoplankton responses to wastewater discharges. A reconnaissance level approach was used in the modeling because the data available to calibrate the model were not sufficient to justify a large number of modeling segments. The hydrodynamic section of WASP4, termed DYNHYD4, was calibrated with hydrodynamic data collected by Pirnie-Harris International (1979), and water quality data were used to calibrate the EUTRO4 segment of the model. A detailed description of the July 1989 WASP4 modeling results and background on the model can be found in Dames & Moore (1990).

The wastewater loads used in the model were selected to represent an ultimate BOD load from the proposed Suez wastewater treatment plant as well as industrial pollutant inputs. Input loads used in the WASP4 model were wastewater loads from an advanced primary treatment process (Table 1), which is comparable to Law 48 discharge. It can be seen that the input loads were conservatively high; the carbonaceous biochemical oxygen demand over 5 days ($CBOD_5$) load (based on the assumption that ultimate or 20 day CBODu is 1.5 times the $CBOD_5$ value) is estimated to be 18,000 kilograms per day (kg/day), while the load used in the model was 53,000 kg/day. The load used in the model is larger to account for industrial wastewater inputs and agricultural drain waste inputs. These unquantified inputs are not believed to be more than 30,000 kg of $CBOD_u$, accordingly, the WASP4 model results should be considered to be more representative of a wastewater discharge from a conventional primary treatment plant than for a Law 48 effluent. Furthermore, the July modeling effort assumed a year 2000 design flow of 200,000 m^3/d, which has now been changed to 130,000 m^3/d for the year 2005.

The July 1989 WASP4 model results are presented in Table 2. After the model stabilizes waste inputs, the model concentrations are within acceptable levels. DO concentrations never drop below 5 mg/l, and chlorophyll a levels predicted by the model are in the range of 11-18 ug/l. These predicted values for chlorophyll a are

231

TABLE 1

Suez Bay Pollutant loads Used in July WASP4 Model Runs

Design Flow = 200,000 m^3

Pollutant	Assumed Advanced Primary Effluent Concentrations, mg/l	Year 2000 Raw Load Kg/da	Year 2000 Law 48 Effluent Load, Kg/da	Year 2000 Primary Effluent Load, Kg/da	Load Used in WASP4	WASP4 Loads With Industry Inputs
$CBOD_5$	60	40,000	12,000	32,000	53,000	101,000
CBODu	90	60,000	18,000	48,000		
TSS	50	40,000	10,000	25,000		
TP	7	1,400	1,400	1,400	5,000	9,000
TKN	2	8,000	400	4,000	3,000	3,000
NO_3	28	3,000	5,600	2,000	3,000	3,000
Fecal Coliforms, MPN/100 ml	5,000	--	--	--	--	--

Note: The WASP4 model calculates CBODu from CBOD5
TSS was not modelled in WASP4

240

Table 2. July WASP4 Model Results for Suez Bay

PARAMETER	PREDICTED RANGE FOR MODEL SEGMENTS
$CBOD_5$, mg/l	0.07 - 0.35
DO, mg/l	5.6 - 6.0
Total Inorganic Nitrogen, mg/l	2.4 - 2.5
Total Inorganic Phosphorus, mg/l	0.75 - 0.81
Chlorophyll a, ug/l	11.4 -17.7

241

significantly higher than values observed in the 1989 monitoring. The higher chlorophyll a results must be viewed with some caution, however. Relatively high concentrations of chlorophyll a may be due to a conservative modeling assumption that there is no settling of nutrients or phytoplankton. While the modeling results must be viewed with caution, the results, even assuming no settling of phytoplankton, predict that Suez Bay can assimilate the modeled nutrient inputs.

Water quality response to wastewater discharges was also examined using a simple model developed by Officer and Ryther (1977). The model is based on classic steady state BOD decay and reaeration processes. The key term in the DO deficit equation is hydraulic detention time of the water body. Modeling by Pirnie-Harris International (1979) indicates that the hydraulic detention time in Suez Bay is on the order of 50 days. With this data, the only remaining input value is the waste load in g/day of ultimate oxygen demand. This oxygen demand should include all waste sources of both carbonaceous and nitrogenous BOD.

The Officer and Ryther model was used to model current conditions, a primary effluent from the proposed wastewater treatment plant, and a Law 48 effluent. Input waste load calculations are presented in Table 3. Again, the model assumes a wastewater discharge of 200,000 m^3/d, and therefore is conservative in its analysis. The model results presented in Tables 4 through 6 indicate that the current discharge should produce a DO deficit of 0.4 mg/l in the wastewater plume. Law 48 and primary effluent DO deficits of 0.3 and 0.6 mg/l, respectively, would be expected in the wastewater plume. These model results are consistent with observed field conditions and WASP4 results.

The modeling results yield the following conclusions:

- Carbonaceous BOD loads from either a Law 48 effluent or conventional primary effluent will not significantly depress DO conditions in Suez Bay.

- Higher ammonia nitrogen loads from a primary effluent will result in a higher WDOD, but a measurable DO sag in Suez Bay will not be significant.

- Phosphorus and nitrogen inputs for either primary or a Law 48 effluent will not result in excessive levels of chlorophyll a; however, chlorophyll a values are predicted to double over existing levels.

Diffuser design data (Pirnie-Harris International 1979) indicate that 0.15 m diameter ports discharged at a depth of 15 m at 4,600 m^3/day will have dilution rates of 52:1 to 54:1. An outfall of 2,000 m will be required in order to reach a depth of 15 meters. A 5 m port spacing will result in a diffuser length of 220 m. A primary effluent will have fecal coliform levels of approximately 1,000,000 MPN/100 ml. A 50:1 dilution will drop the fecal coliform level to 2,000 MPN/100 ml at the water surface over the diffuser outfall.

242

TABLE 3

BOD Load Inputs to Officer and Ryther Model

	Current Conditions	Law 48 Effluent Load	Primary Effluent Load
Suez WWTP Flow, m^3/da	60,000	200,000	200,000
Suez CBODu Load, Kg/da	23,400	18,000	48,000
Suez NBODu Load, Kg/da*	18,000	1,830	18,300
Industrial CBODu Load, Kg/da	23,400	23,400	23,400
Overall BODu Load, Kg/da	64,800	43,230	89,700

*Based upon an assumption that NBODu = 4.57 x TKN load.

Note: CBODu = 20 day carbonaceous BOD
NBODu = 20 day nitrogeneous oxygen demand
BODu = CBODu + NBODu

243

TABLE 4

Officer and Ryther BOD Model Results for Current Discharge

---------- Waste Oxidation Model ----------

Water Body: Suez Bay, Current Conditions (Suez City load doubled for industry loads)
(Industrial input = 15,600 Kg/day CBOD5 = 23,400 Kg/da CBODu.)

Volume, V, m^3: 771,000,000

	River Flow, R m^3/day	River Name			
1.	15,000,000	Tidal Flushing	Reaeration, k2, 1/day =	0.2	From Officer
2.	35,000	Misc.	Deoxygenation, k1, 1/day =	0.4	and Ryther
3.	200,000	Wastewater			
4.					

Volume-avg. freshwater fraction, f =

Sum of input flows: 15,235,000 m^3/day

Detention time, V/R=T, days = 50.61 days

Waste discharge oxygen demand, W, gm/day = 64800000

W/V = 0.08

WDOD = Waste DO deficit, mg/l

WDOD = W/(V/T)*((1-e^-k2T)/(k2T)-(1-e^-k1T)/(k1T))*(k1/(k1-k2))

WDOD = 0.4 mg/l

Note: If WDOD is greater than 10, the receiving water will be anoxic.
If WDOD is less than 1.0, the receiving water will not have a DO sag.

TABLE 5

Officer and Ryther BOD Model Results for Law 48 Effluent

---------- Waste Oxidation Model ----------

Water Body: Suez Bay, Year 2000 Conditions with Law 48 Effluent
(Industrial input = 15,600 Kg/day CBOD5 = 23,400 Kg/da CBODu.)

Volume, V, m^3: 771,000,000

	River Flow, R m^3/day	River Name			
1.	15,000,000	Tidal Flushing	Reaeration, k2, 1/day =	0.2	From Officer
2.	35,000	Misc.	Deoxygenation, k1, 1/day =	0.4	and Ryther
3.	200,000	Wastewater			
4.					

Sum of input flows: 15,235,000 m^3/day

Detention time, V/R=T, days = 50.61 days

Waste discharge oxygen demand, W, gm/day = 43230000

W/V 0.06

WDOD = Waste DO deficit, mg/l

WDOD = W/(V/T)*((1-e^-k2T)/(k2T)-(1-e^-k1T)/(k1T))*(k1/(k1-k2))

WDOD = 0.3 mg/l

Note: If WDOD is greater than 10, the receiving water will be anoxic.
If WDOD is less than 1.0, the receiving water will not have a DO sag.

245

TABLE 6

Officer and Ryther BOD Model Results for Primary Effluent

---------- Waste Oxidation Model ----------

Water Body: Suez Bay, Year 2000 Conditions with Primary treatment (160 mg/l CBOD5)
(Industrial input = 15,600 Kg/day CBOD5 = 23,400 Kg/da CBODu.)

Volume, V, m^3: 771,000,000

	River Flow, R m^3/day	River Name			
1.	15,000,000	Tidal Flushing	Reaeration, k2, 1/day =	0.2	From Officer
2.	35,000	Misc.	Deoxygenation, k1, 1/day =	0.4	and Ryther
3.	200,000	Wastewater			
4.					

Sum of input flows: 15,235,000 m^3/day

Detention time, V/R=T, days = 50.61 days

Waste discharge oxygen demand, W, gm/day = 89700000

W/V = 0.12

WDOD = Waste DO deficit, mg/l

WDOD = W/(V/T)*((1-e^-k2T)/(k2T)-(1-e^-k1T)/(k1T))*(k1/(k1-k2))

WDOD = 0.6 mg/l

Note: If WDOD is greater than 10, the receiving water will be anoxic.
If WDOD is less than 1.0, the receiving water will not have a DO sag.

3.3.1.3 July Sediment Sampling

Sediment samples were collected during the July 1989 water quality sampling effort. Sediment samples were characteristically a gray, silty sand with a low volatile organic content and odor (Dames & Moore, 1990). The exception was near the drain discharge, where black organic material was present with strong hydrogen sulfide odors. Fauna was sparse in all sediment samples; however, there was no evidence to suggest that thermal stratification occurs within the bay area, or that subsequent anoxic conditions exist in the bottom layer other than near El Saal Drain.

3.3.2 November-December 1989 Findings

3.3.2.1 Currents and Circulation

Information on currents and circulation in the nearshore zone around the El Saal Drain outlet to Suez Bay were obtained from two major sources. Data over a 1-month period were obtained from the moored current meter at Station 5 (over 800,000 readings accumulated by the meter), 78 current profiles, and drogue tracks. Although these data cover only a small part of the year, they provide valuable information over approximately a full lunar tidal cycle. Additionally, an indication of predominant mean flow integrated over a long period of time is provided by the accumulation of amoebic cysts in seafloor sediments (Section 3.3.2.4).

Currents measured at Station 5, at an instrument depth of 2.5 m in a total water depth of 5.2 m, are plotted in Figure 3. The upper panel shows predicted tidal heights at Port Tewfiq (US National Ocean Survey 1988); actual tides were not measured during this study. Correlative wind speed and direction data are plotted in Figure 4, along with air temperature at Port Tewfiq and seawater temperature at Station 5 (upper panel). (By convention, water currents are described by the direction <u>in which</u> they flow, whereas wind directions are given as the direction <u>from which</u> they blow.) Winds experienced during the November-December field study were predominantly northerly, with approximate average speeds of 2 m/sec. Stronger winds (2-4 m/sec or more) generally came from the north and northwest. Weaker speeds (<2 m/sec) were associated with more variable directions. These values agree with earlier measurements made in the winter of 1979 (Pirnie-Harris International 1979), where over 65% of all measured winds approached from the north and northwest sectors. They are also representative of annual mean winds; unpublished data provided by the Suez Canal Authority show 59% of all winds approaching from compass directions between 315 and 014°, with an annual mean speed of 4.4 m/sec. Southerly and southeasterly winds occur most frequently in the winter months between December and April, but do not exceed about 15% of all measurements.

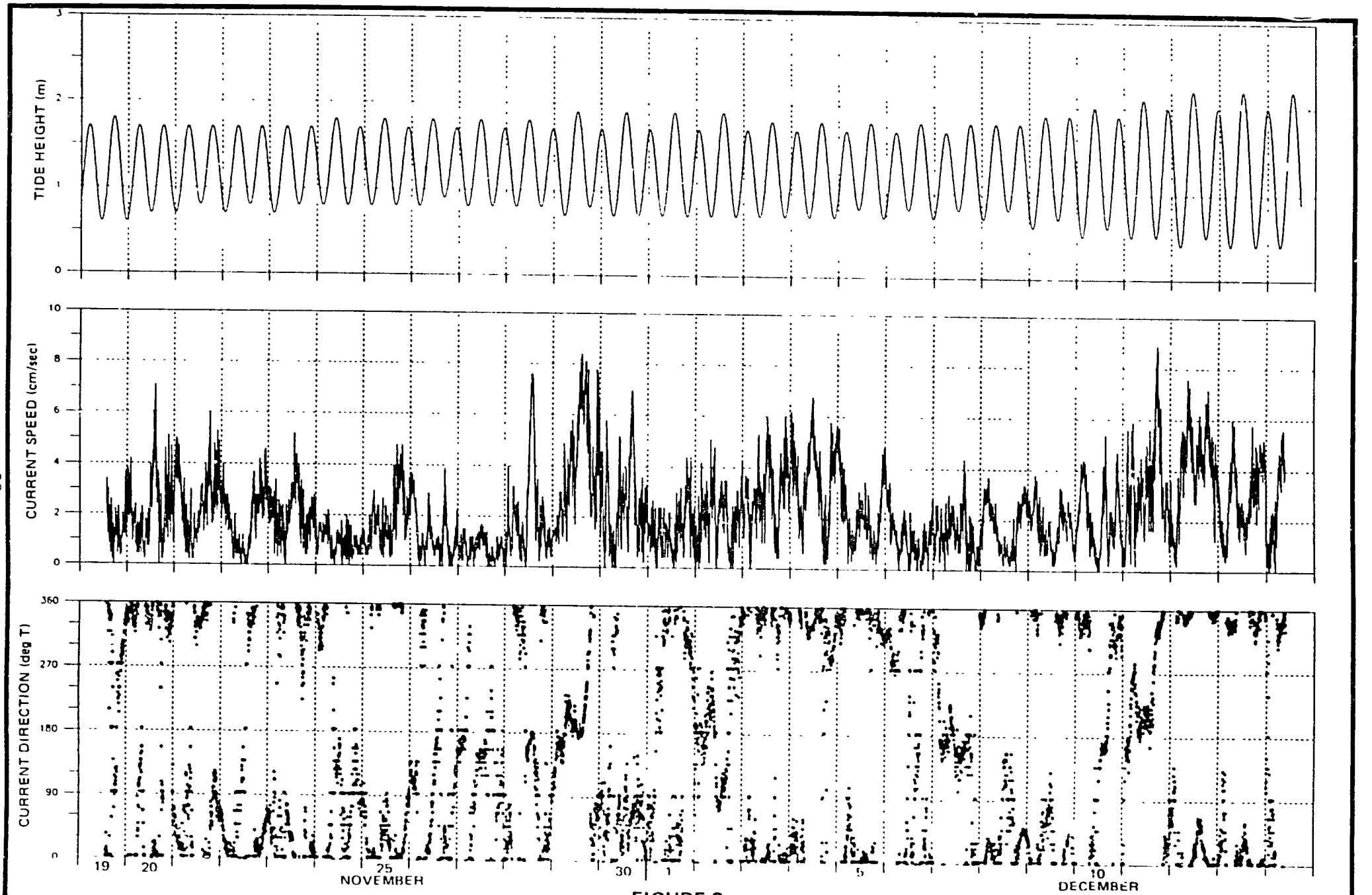


FIGURE 3
CURRENT METER RECORDS FROM STATION 5,
NOVEMBER – DECEMBER 1989

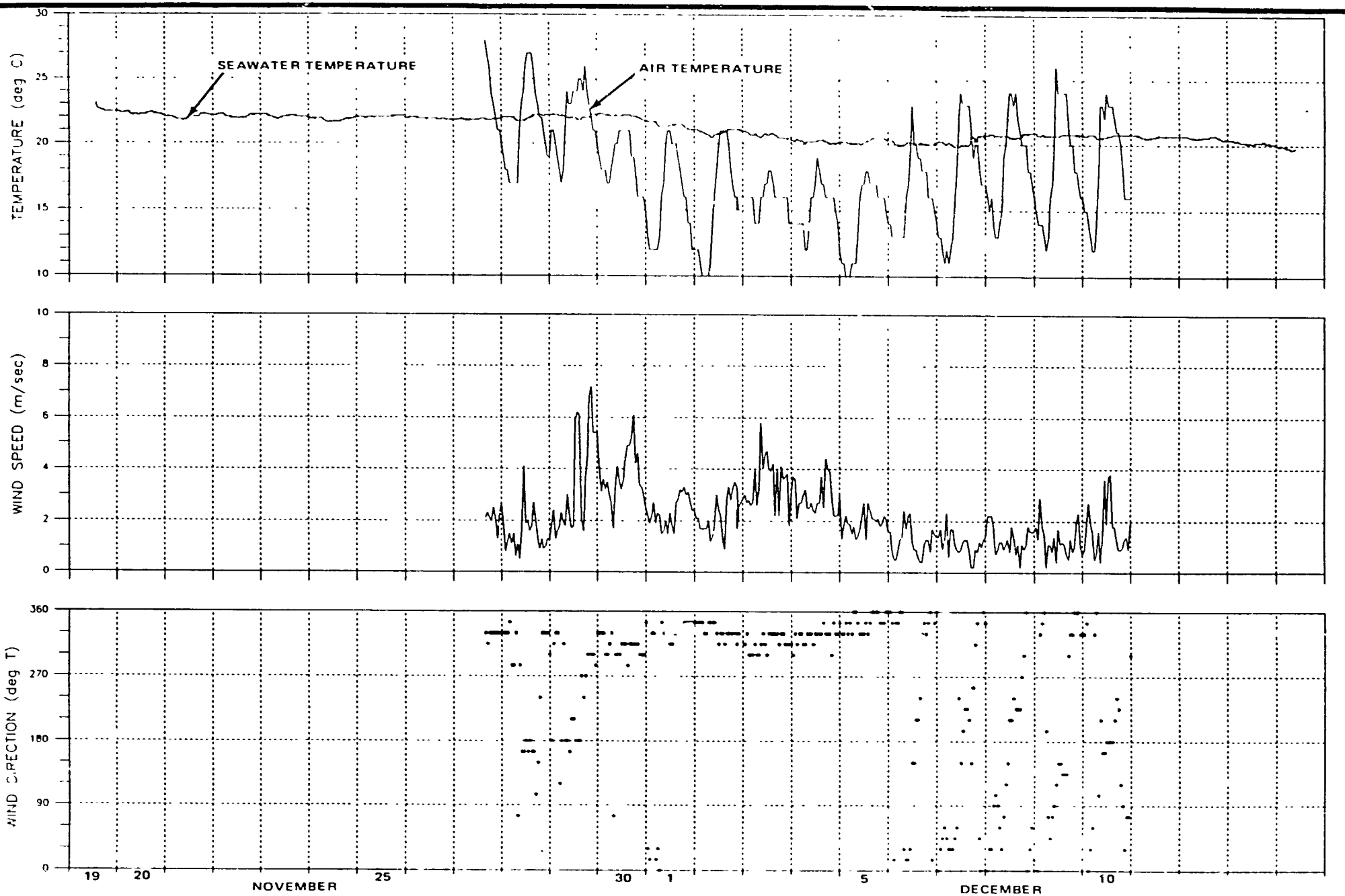


FIGURE 4
METEOROLOGICAL DATA FOR NOVEMBER-DECEMBER 1989

Dames & Moore

The predicted differences between successive high and low tides that occurred during the study period ranged from 0.8 to 1.8 m; the mean range at Suez is reported to be 1.2 m.

Table 7 shows the joint distribution of current speed and direction at Station 5; that same information is plotted as a current rose in Figure 5. Figure 6 is a progressive vector diagram constructed by progressively connecting each of the individual current vectors head to tail. Several relationships can be seen from the plotted data:

- Flow from the Station 5 meter (located at mid-depth) over the period of record was strongly northward, with only 4 periods of southerly flow, each lasting for about 24 hours (Figure 6). About 50 percent of all current measurements at that station were directed to the north (between 337 and 23 degrees); only about 11 percent were directed to the south.

- Current speeds were very low (center panel of Figure 3), with the maximum speed recorded of about 8 cm/sec (0.15 knots) and with 52 percent of all measured speeds of 2 cm/sec (0.04 knots) or less.

- Alongshore components of subsurface flow at Station 5 were small, but showed a slightly greater occurrence of easterly flow.

- While there is some suggestion of variability in currents at tidal frequencies in the data plotted in Figures 3 and 4, the correlation appears weak, which is not surprising with such low current speeds. The flow regime in the northwestern part of the bay does not appear to be tidally driven.

Vertical profiles of current speed and direction were collected several times at the six primary stations in the northwest sector of the bay (including two sets of measurements over a semi-diurnal tidal cycle), at four additional stations in other parts of the bay, and at two stations located immediately off the power plant discharge and the Suez Oil Company discharge. All current profiles are graphically plotted (along with CTD and DO profiles) and presented in Dames & Moore (1990). Profiling data generally support the following observations:

- Current speeds are generally very low, rarely exceeding 20 cm/sec, with a few notable exceptions.

- Current directions are highly variable, which is typical with such low speeds. The manner in which they progressively change with depth suggests that eddies migrate past the moored meters.

Table 7. Current Speed and Direction Frequency Distribution, Station 5

FREQUENCY IN PERCENT

DIRECTION	Intervals of Speed in cm/sec 0.0 2.0	2.0 4.0	4.0 6.0	6.0 8.0	8.0 10.0	>10.0	PERCENT TOTAL	MEAN SPEED
N	11.6	9.8	3.3	0.4			25.2	2.2
NNE	5.5	5.3	0.9	0.1			11.8	2.1
NE	4.3	2.8	0.7				7.8	2.0
ENE	3.1	1.6	0.7	0.2			5.7	2.2
E	5.2	1.2	0.1				6.5	1.2
ESE	2.0	0.8					2.8	1.6
SE	3.0	0.4					3.4	1.2
SSE	2.6	1.3	0.3	0.1			4.3	2.0
S	2.8	1.0	0.4	0.6	0.1		4.9	2.4
SSW	0.5	1.2	0.5	0.1			2.4	3.1
SW	0.6	0.7	0.2	0.1			1.5	2.6
WSW	0.5	0.3	0.1				0.9	2.0
W	1.8	0.4	0.2	0.1			2.5	1.6
WNW	1.3	0.6	0.3				2.3	2.4
NW	2.6	2.2	0.7	0.1			5.6	2.4
NNW	4.2	5.3	2.3	0.3			12.2	2.8
TOTALS	51.7	35.0	10.9	2.2	0.3	0.0	100.0	

TOTAL OBSERVATIONS: 7172

Note: Values less than 0.05 are not printed in the table, but are computed in totals. Totals, therefore, differ slightly from the sums of the columns because of rounding errors.

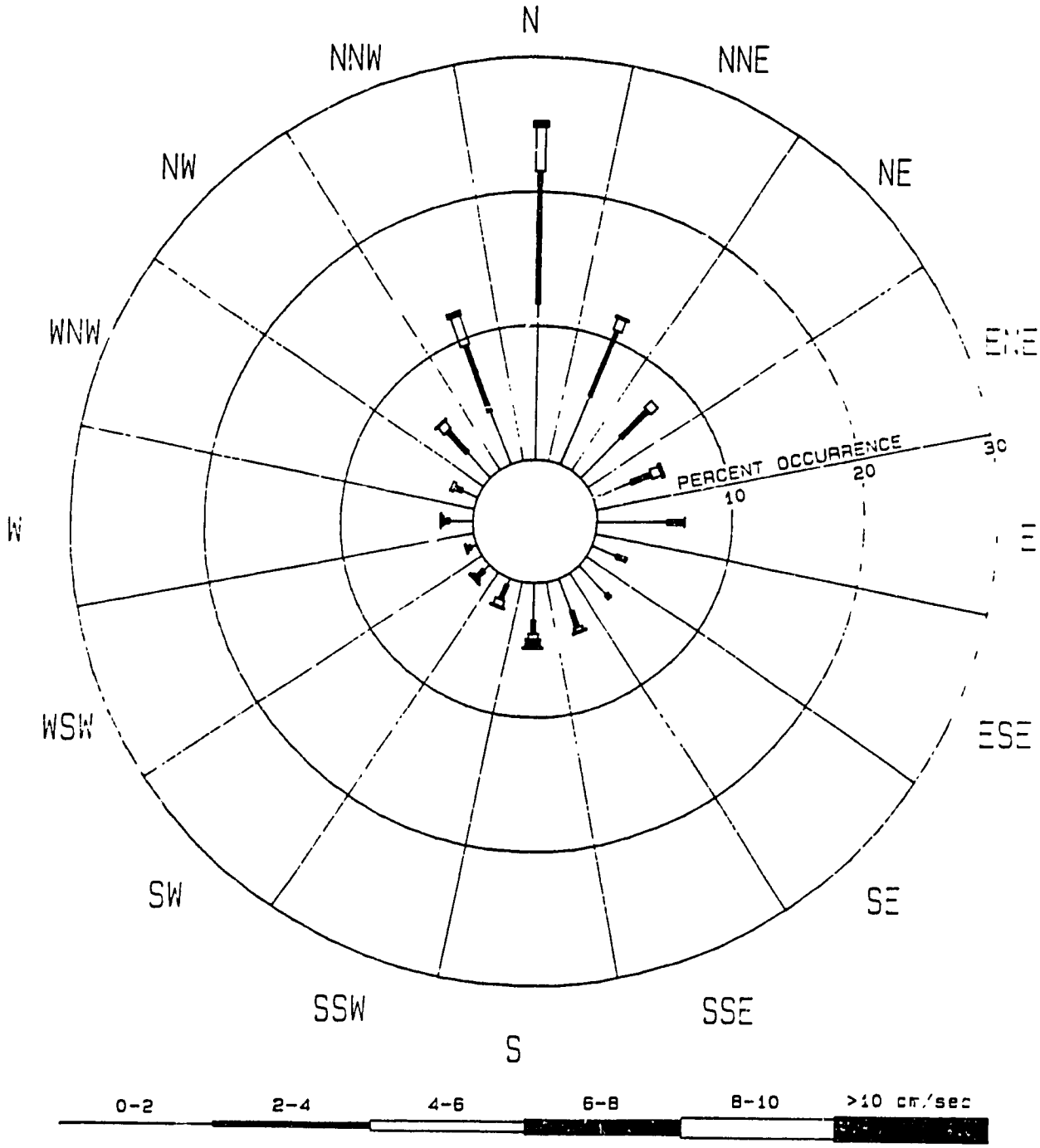


FIGURE 5
CURRENT ROSE FOR STATION 5,
November-December 1989

Dames & Moore

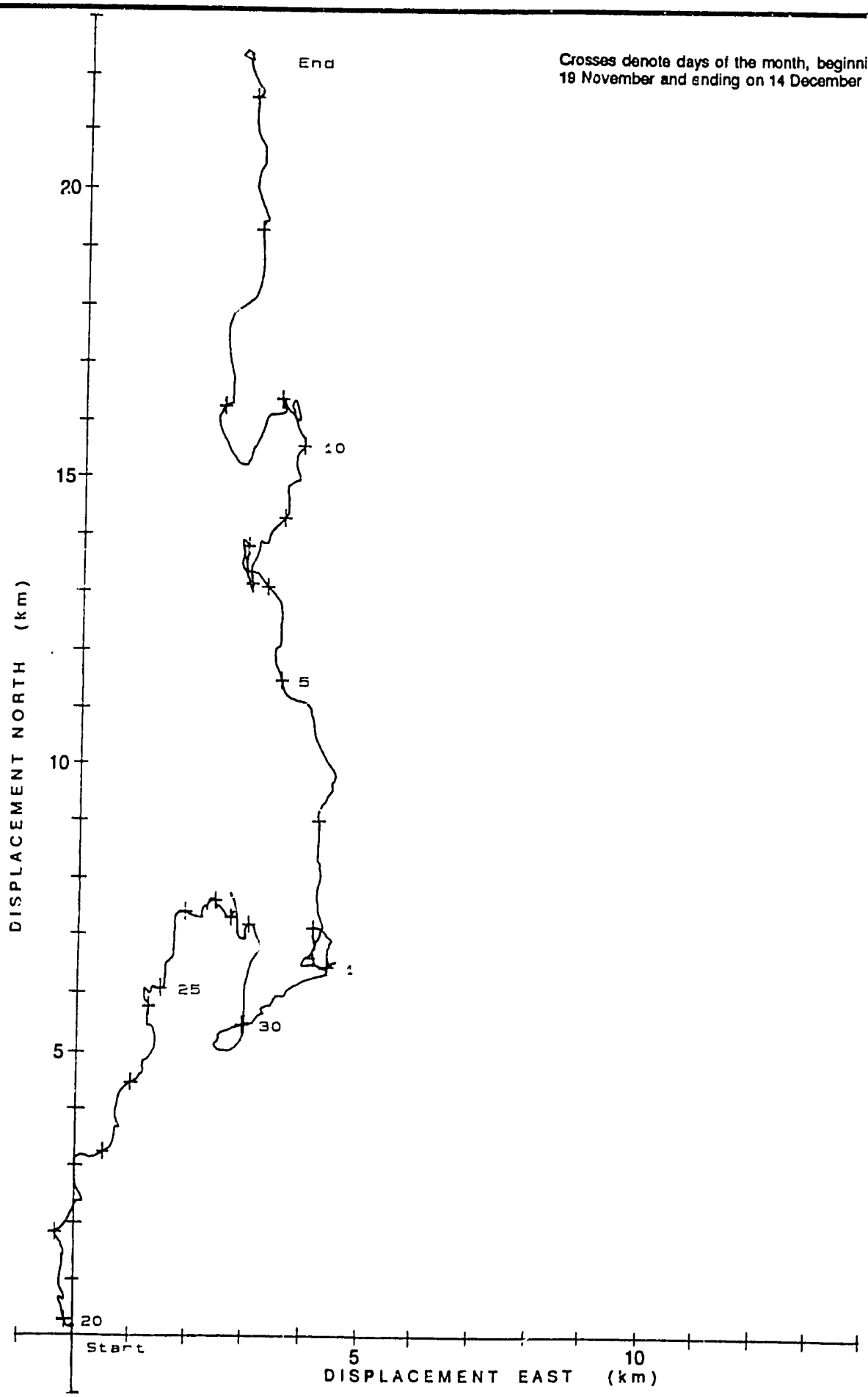


FIGURE 6
PROGRESSIVE VECTOR DIAGRAM
FOR CURRENT AT STATION 5,
November-December 1989

Dames & Moore

- The deeper stations (6, 7, 8, and 9) consistently show very rapid currents between 10 and 15 m depth; speeds of 100-150 cm/sec (2-3 knots) are common (Figure 7 is representative of the phenomenon). Speeds tend to decrease once again below 15 meters. No corresponding changes in water mass characteristics seem to be associated with the high currents.

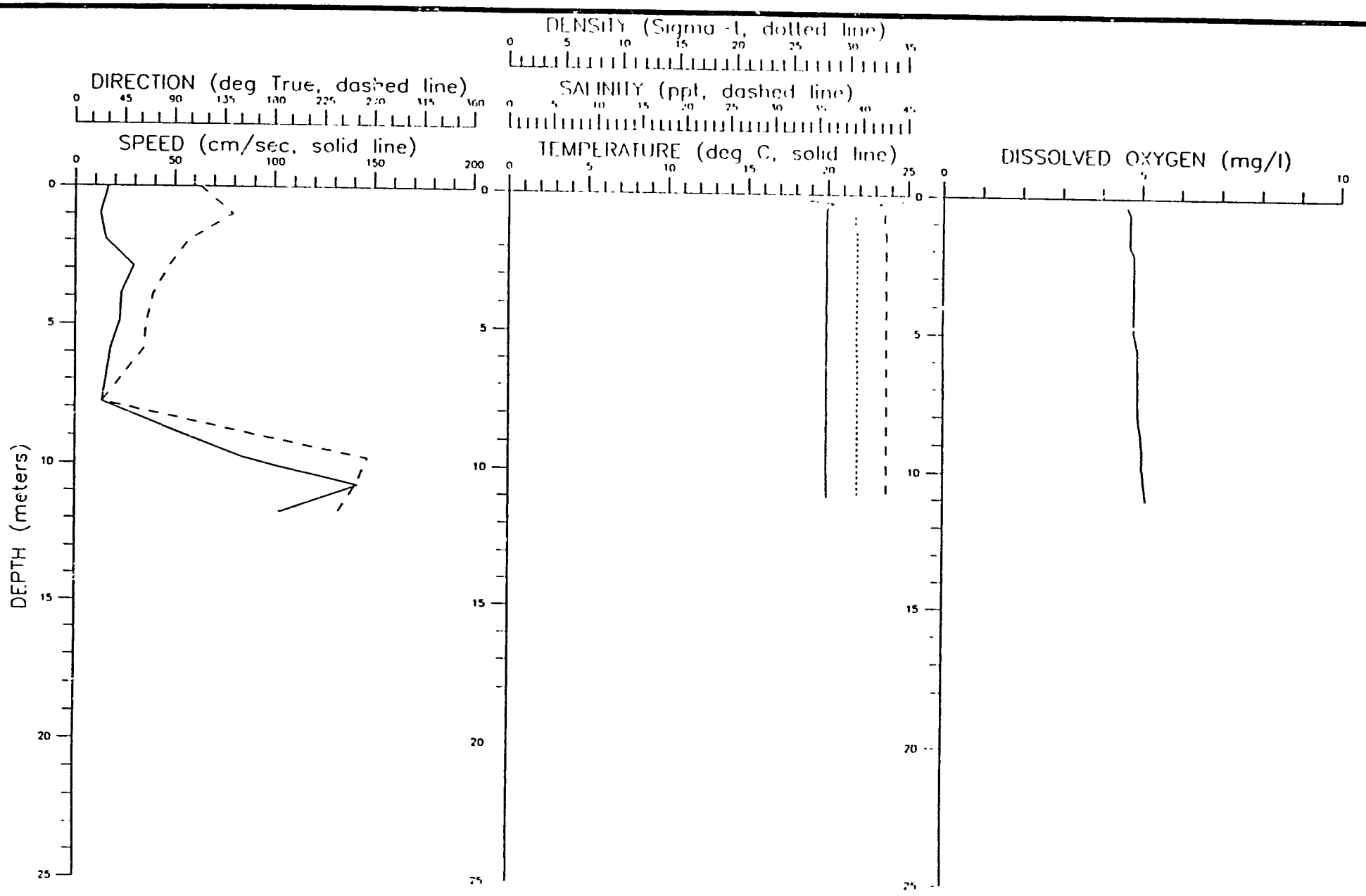
The origin, nature, and persistence of these jets are unknown, but they do occur in the vicinity of the proposed 10 m submarine outfall.

Current flow conditions at Station 6, nearest the proposed submarine discharge, are shown in Figure 8. The information is derived from the current meter profiling records. All 12 of the speed and direction profiles collected during this study are overplotted on common axes. Speeds at the surface were low, between 5 and 20 cm/sec, and most commonly decreased with depth down to the 8-10 m depth, where they increased dramatically to a maximum of 150 cm/sec (approximately 3 knots). Flow directions are highly variable, but are generally southerly in the upper 5 m of water, generally northerly in the 5-10 m layer, and then southerly once again below 10 m (where the high speed jet was observed). As was also the case for Station 5, surface waters generally move southward while subsurface waters move northward.

In the northwestern sector of the bay, where both the existing surface drain and the proposed site of the submarine outfall are located, the November-December data indicate that the dominant flow regime appears to be a two-layered system. Under the most common circumstances, with the dominant northerly winds. the surface layer is transported to the south (away from the shoreline), and is replaced by a subsurface layer moving toward the shoreline. This phenomenon was visually observed on several occasions during the November-December field work. Suspended particulates in the upper few centimeters of water were seen moving offshore at speeds estimated at 20-30 cm/sec, while particulates in deeper layers were seen moving sluggishly toward shore.

The drogue tracks for releases at Station 1 on 6 December and Station 6 on 9 December are plotted in Dames & Moore (1990). While winds are predominantly northerly in the Suez Bay area, southerly winds blew during the period of the drogue study on December 6; within 3 hours of deployment at Station 1, all 5 drogues were grounded on the northern shore of the bay. They had all moved northeasterly from their original locations, at nearly right angles to the wind, indicating an easterly alongshore transport of water during that time. The drogues deployed at Station 6 three days later all moved toward the south; winds were light and variable during the deployment period. The drogues drifted progressively apart as they moved southward.

During the period of this most recent field survey, alongshore current flow off the El Saal Drain showed a net easterly movement, as demonstrated by the progressive vector plot constructed from Station 5 current data (Figure 6) and by the drogue tracks from 6 December. This finding is not necessarily at variance with earlier conclusions reached by Meshal (1967) and Pirnie-Harris International (1979), who both postulated



SUEZ BAY OCEANOGRAPHIC STUDY
Station: 6 Date: 03 Dec 89 Time: 0840

FIGURE 7
CURRENT AND WATER MASS PROFILES, STATION 6, 3 DEC. 1989; 0840.

Dames & Moore

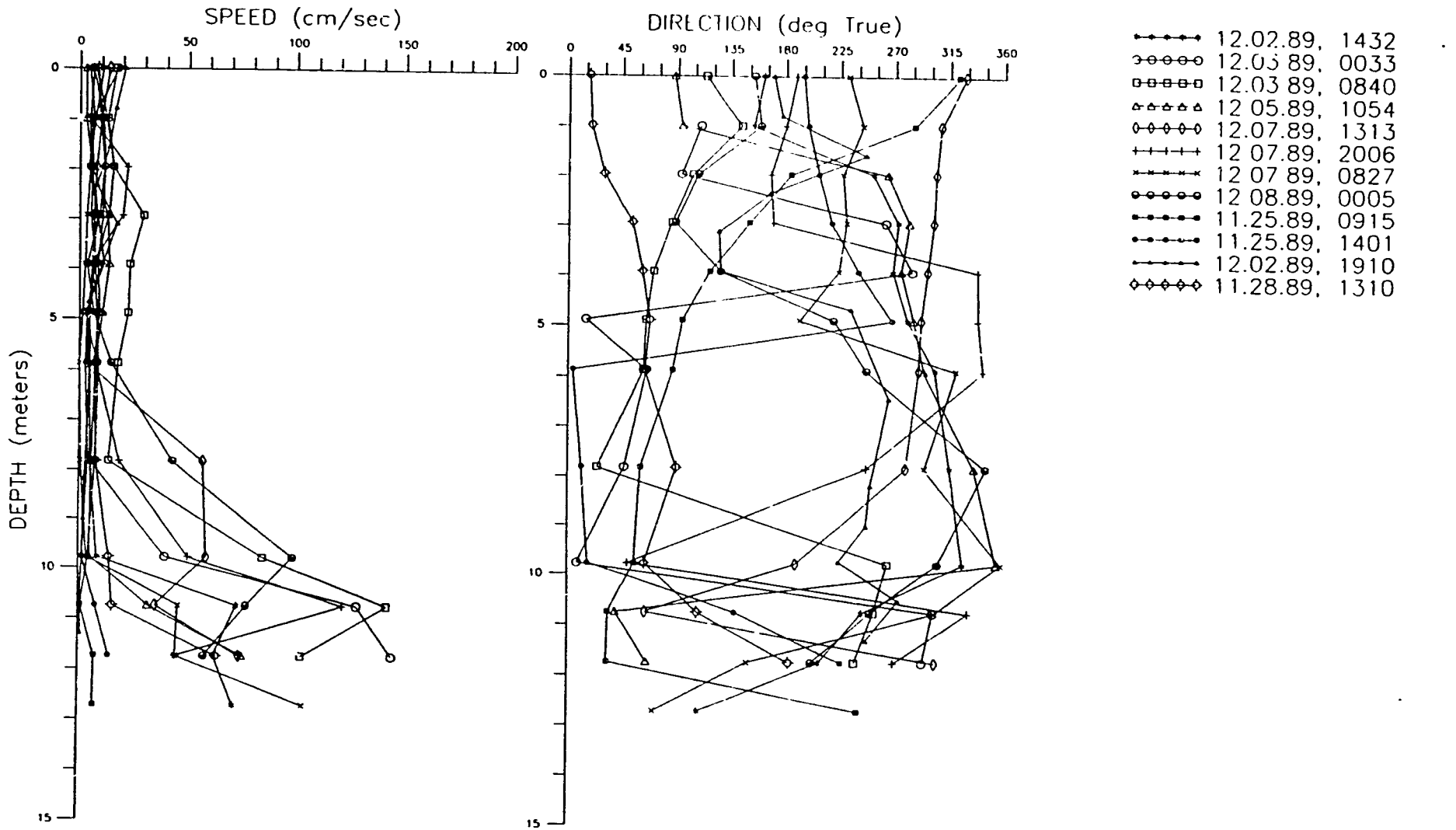


FIGURE 8
CURRENT PROFILE DATA FROM STATION 6,
November-December 1989

a counterclockwise circulation pattern in Suez Bay as a whole. Meshal (1967) lacked current data from the northwestern quadrant of the bay, and hypothesized counterclockwise circulation based primarily on surface current data from the central and eastern parts of the bay. Pirnie-Harris International (1979) likewise based their conclusion on current profile data collected over a number of days at varying tidal stages at stations distributed elsewhere throughout the bay. Such a counterclockwise pattern may in fact exist in the central and southern parts of the bay, while at the same time a clockwise gyre may exist along the northern shore to the west of El Mina El Gedida.

3.3.2.2 Marine Water Quality

Water quality data collected in November-December 1989 are reported in detail in Dames & Moore (1990). Based on both visual observations during the field sampling program, and on the CTD profiles in (Dames & Moore, 1990), it is clear that wastewater from the El Saal Drain spreads out over the nearshore surface of the bay in a buoyant, freshwater lens. Figure 9 is representative of the nearshore water column profiles, and clearly shows this low salinity lens. This layer varies in thickness, but was never greater than 1 m thick and was often only a few centimeters thick. The maximum offshore (i.e., southward) extent of this surface layer that was observed during the study was approximately 1.5-2 km off the mouth of the El Saal Drain.

Salinity in Suez Bay is high, falling generally between 42 and 43 ppt. Subsurface waters (below 1-2 m) and offshore waters showed remarkably isohaline conditions during the study (Dames & Moore, 1990), whereas nearshore surface salinity was much more variable.

DO values were generally similar throughout the water column at each station, with occasional lower DO values near the bottom. Typical DO values for the water column at each station for each date during the November-December 1989 surveys are presented in Table 8. DO was supersaturated at all stations on November 25 and at Stations 4, 5, and 6 on November 28. DO values dropped in early December with lowest values observed on December 2-3 (52-74% saturation). Percent saturation increased to 72-92% on December 5. Saturation values on November 25 were highest at Stations 2 and 4, perhaps due to relatively higher chlorophyll a levels. Station 6 DO concentrations were generally closest to saturation, perhaps reflecting that this station appears to be usually outside the zone of impact of the El Saal Drain.

Average surface water quality data for all water quality sampling stations are presented in Table 9; values recorded for TP and TKN as well as the means and standard deviations are plotted by station in Figures 10 and 11. They indicate the variability in the data over the 1-month period. Concentrations of all water quality constituents in Suez Bay were highest at Station 1 with the exception of chlorophyll a, which was highest at Station 3. Station 3 is nearest the drain from the fertilizer plant.

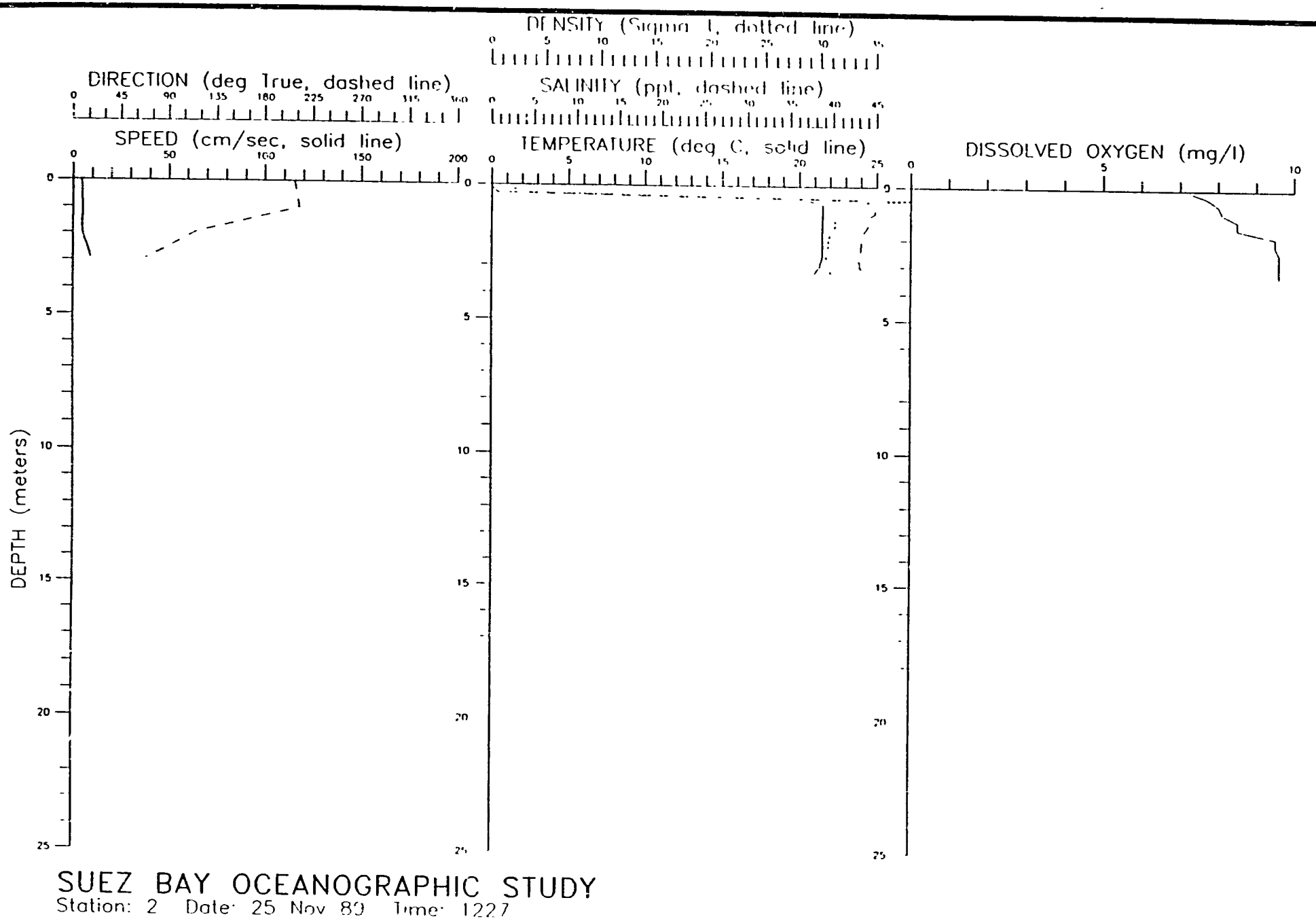


FIGURE 9
CURRENT AND WATER MASS PROFILES, STATION 2, 25 NOV. 1989; 1227.

Table 8. Typical Water Column DO Concentrations in November - December 1989

Date	Station [a] 1	2	3	4	5	6	Average [b] Temp
Nov 25	8.2	9.0	8.4	8.8	8.5	8.3	21.5
Nov 28	7.0	7.0	6.8	7.7	7.5	7.2	21.5
Dec 2 1300	2.5	4.8	4.5	4.8	5.4	5.2	20.5
Dec 2 1800	4.2	3.5	4.5	4.2	5.0	5.0	20.3
Dec 3 0300	4.0	3.3	4.1	5.2	6.2	5.0	20.5
Dec 3 0700	4.2	4.0	3.8	4.1	4.8	4.7	20
Dec 5 1030	5.2	5.6	5.2	5.5	6.3	6.6	19.7
Dec 7 0700	5.0	4.2	5.0	5.0	5.8	6.7	19.0
Dec 7 1200	4.5	2.5	5.6	4.8	5.7	6.7	19.0
Dec 7 1830	5.2	4.0	5.5	5.5	6.0	6.4	20.0
Dec 8 0000	4.7	4.3	5.0	5.2	5.2	6.2	20.0

% Saturation	1	2	3	4	5	6	Sat DO
Nov 25	115	127	118	124	120	117	7.1
Nov 28	99	99	96	108	106	101	7.1
Dec 2-3	52	54	59	64	74	69	7.2
Dec 5	72	78	72	76	88	92	7.2
Dec 7-8	67	52	73	71	79	90	7.2

a: DO in mg/l
b: Average temp. in °C

Table 9. Average Concentrations for Water Quality Constituents
November - December, 1989

Station Means	Station	BOD mg/l	COD	PO4-P	TP	TKN	NH3	NO3	SiO2	Conduct umos/cm	Coliform #/100 ml	Chlorophyll a - ug/l
Average	1	12.23	147	0.19	0.47	3.52	0.70	0.04	0.34	56,971	2,355	1.4
Std Day	1	15.22	44	0.24	0.51	2.70	0.77	0.06	0.22	2,331	3,965	0.8
Averages	2	5.93	172	0.07	0.16	2.05	0.46	0.04	0.15	60,342	2,346	2.8
Std Day	2	5.61	76	0.08	0.17	1.35	0.59	0.03	0.07	2,903	3,330	4.3
Averages	3	7.93	170	0.10	0.23	1.86	0.42	0.03	0.16	56,692	2,329	3.3
Std Day	3	9.42	3[illegible]	0.16	0.31	1.01	0.33	0.03	0.08	6,404	3,541	4.7
Averages	4	7.21	181	0.11	0.29	2.13	0.58	0.05	0.47	58,079	1,985	3.0
Std Day	4	4.89	49	0.09	0.26	1.11	0.50	0.07	0.60	3,321	2,547	4.3
Averages	5	5.81	138	0.06	0.15	1.42	0.51	0.04	0.44	54,954	732	2.5
Std Day	5	6.57	34	0.03	0.09	1.12	0.43	0.05	0.93	4,242	777	4.4
Averages	6	5.77	187	0.04	0.08	1.03	0.52	0.04	0.25	58,417	936	1.2
Std Day	6	6.58	55	0.02	0.05	1.02	0.54	0.05	0.42	5,177	1,739	1.1
Averages	El Saal	747	1,071	1.90	4.02	37.63	3.72	0.33	2.64	29,047	20,837	--
Std Day	Drain	404	716	0.33	0.93	6.13	0.56	0.40	1.87	32,236	13,876	--
Average	1-4	7.95	172	0.114	0.29	2.30	0.55	0.05	0.34	58,040	2,164	2.73

TP, PO4-P, TKN, and BOD concentrations were higher at Stations 1 through 5 than at Station 6. Fecal coliform levels at Stations 1 through 4 were higher than at Stations 5 and 6, and fecal coliform levels were higher than 200 organisms/100 ml (a criterion established by the United Sates for waters suitable for total body contact) at all stations. The low chlorophyll a values at Station 1 may be attributable to toxicity effects, perhaps from the oil in the vicinity, as there appeared to be adequate levels of nutrients to sustain much higher levels of chlorophyll a than were observed.

Water clarity appeared to be generally good during the field studies, with the bottom usually visible at the nearshore stations (Table 10). Suspended particulates were usually visible at Stations 1, 2, and 3 (nearest the El Saal Drain). Lorenzen (1972) presented the following relationship between chlorophyll a and the depth of 1% light transmission in open ocean waters:

$$\ln(\text{total chl } a) = 13.3 - (2.83)\ln(\text{depth of } 1\% \text{ light})$$

where: total chl a is in mg/m^2; and
depth of 1% light = $4.61/k_e$.

Thomann and Mueller (1987) report that k_e = 1.8/Secchi depth. Combining the equations and using chlorophyll a data from November-December 1989, calculated Secchi disk transparency should be higher. The fact that water clarity is lower is not surprising; Suez Bay is a shallow, nearshore environment with significant amounts of non-algal sources of turbidity.

In bright daylight, light intensity near the water surface generally appears to be above the saturation level for marine phytoplankton. As a result, maximum phytoplankton production typically occurs at depths between 5 and 20 m (depending on light intensity) and falls off sharply above these depths (Tait and De Santo 1972). Since much of the study area is in shallow water and may be within the zone of light inhibition of phytoplankton, chlorophyll a levels are likely to be lower than what would be expected based on nutrient levels. Thus, light may be the limiting factor for phytoplankton productivity in northwestern Suez Bay.

The nutrient data were evaluated to determine the effect of nitrogen and phosphorus upon phytoplankton growth; nitrogen and phosphorus are generally the limiting nutrients controlling phytoplankton productivity in coastal waters. Linear regressions between total inorganic nitrogen (TIN), total inorganic phosphorus (TIP), total nitrogen, or TP and chlorophyll a did not indicate any conclusive relationship, suggesting that primary productivity is limited by a factor other than nutrients. The average atomic TN:TP ratio for the November-December data was 33:1, while the TIN:TIP ratio was 24:1. The average phytoplankton intracellular ratio of nitrogen and phosphorus is 16:1 (Bowie et al. 1985); accordingly phosphorus would control growth if other factors were not limiting growth.

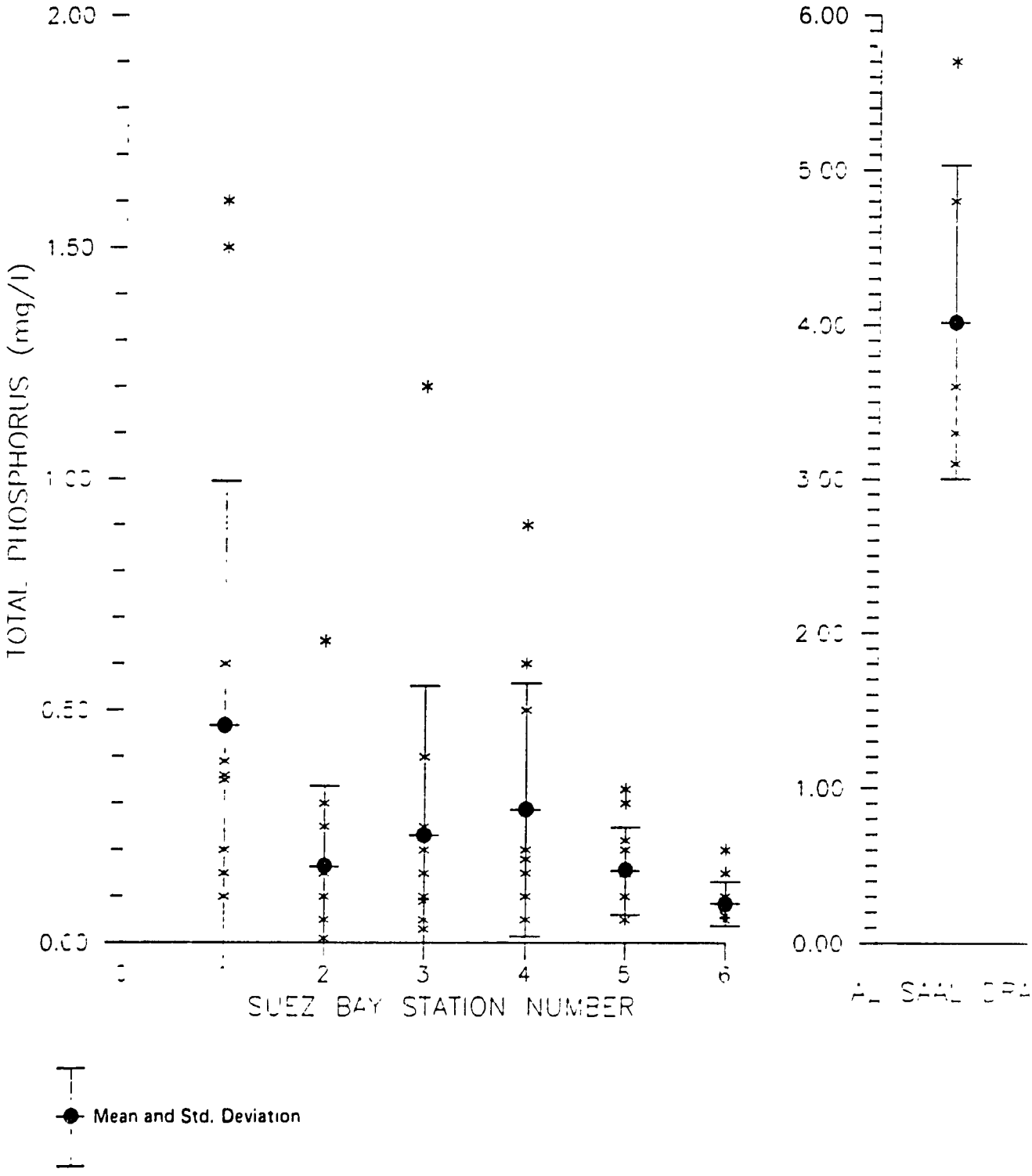


FIGURE 10
TP CONCENTRATIONS IN SUEZ BAY AND AL SAAL DRAIN
November-December 1989

Dames & Moore

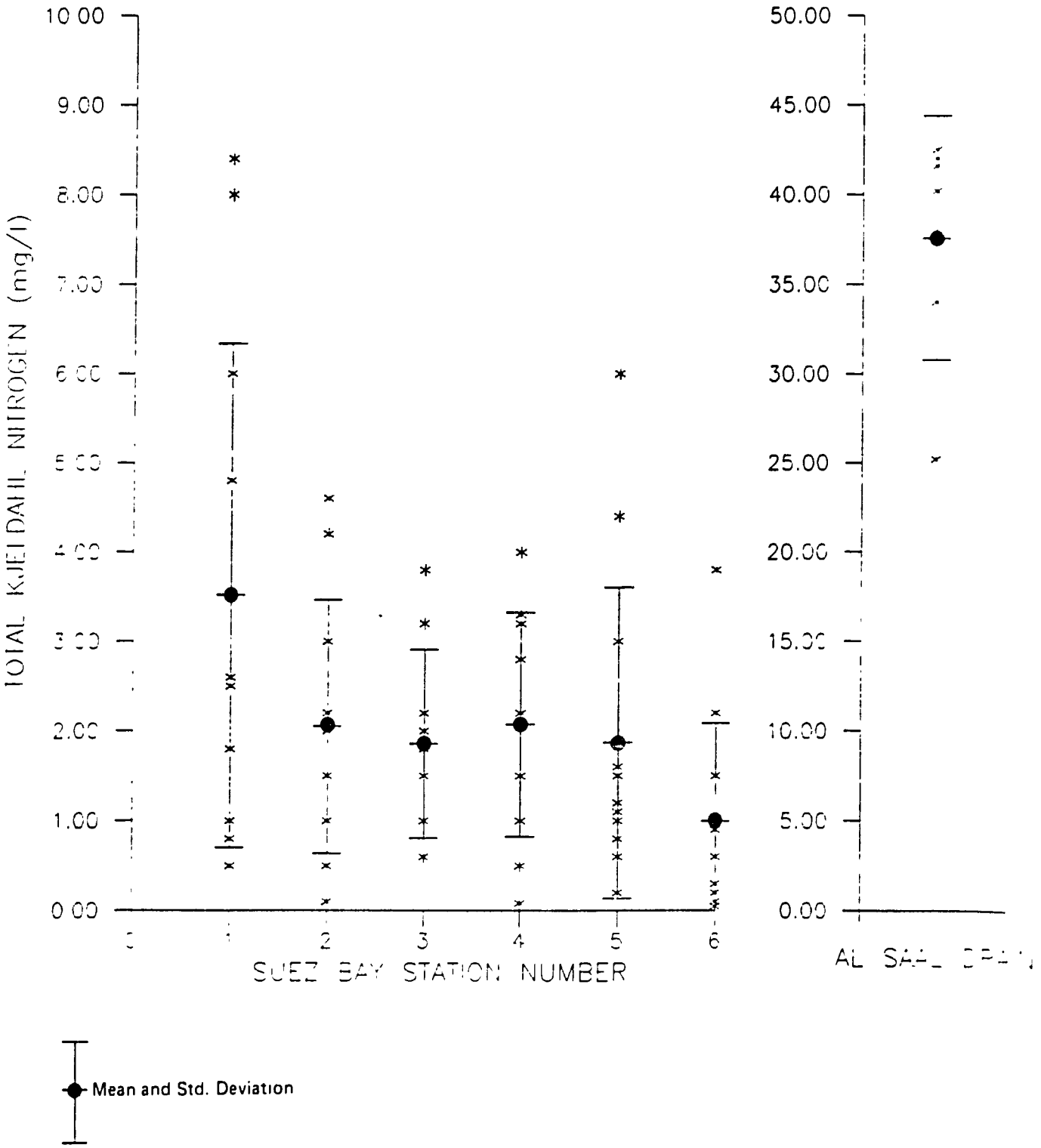


FIGURE 11
TKN CONCENTRATIONS IN SUEZ BAY AND AL SAAL DRAIN,
November-December 1989

Dames & Moore

Table 10. Secchi Disk Measurements of Water Clarity, November-December 1989

	STATION [a]					
Date	1	2	3	4	5	6
11/25	3.3(b)	2.3(b)	3.0(b)	3.0	2.8	4.0
11/25	-	-	-	-	3.2	4.7
11/28	2.6(b)	2.4	3.3(b)	2.3	2.5	3.5
12/02	1.8	3.5(b)	3.5(b)	4.0	6.0(b)	10.0
12/03	2.8(b)	2.5(b)	2.8(b)	3.5	5.0	6.0
12/05	2.6(b)	2.3(b)	2.3(b)	4.0(b)	6.0(b)	9.5
12/07	3.5(b)	3.3(b)	3.3(b)	3.8	6.6(b)	8.6
12/07	2.6(b)	2.5(b)	2.8(b)	2.1	5.8(b)	8.9
Means	2.7	2.7	3.0	3.2	4.7	6.9

a: Secchi depth in meters; (b)= visible bottom

The chlorophyll a, BOD, and water transparency data from November-December, 1989 were similar to data collected in July, 1989. The nutrient concentrations, however, were significantly higher in November-December than in July. The average concentrations of nutrients for both periods are presented below for Stations 5 and 6 (Figures 1 and 2):

Period	TP (mg/l)	PO4-P (mg/l)	NO3-N (mg/l)	NH3-N (mg/l)	TKN (mg/l)	Chl a (ug/l)
July	0.023	0.01	0.124	0.22	0.41	3.1
Nov-Dec	0.115	0.05	0.040	0.51	1.23	1.9

The significantly higher concentrations of TP, PO4, NH3, and TKN in the winter are consistent with seasonal patterns found in temperate marine ecosystems (Tait and De Santo, 1972). This is surprising, considering that Suez Bay is part of the tropical Red Sea ecosystem. It is possible that nutrients are accumulating in the Suez Bay water column in the winter because the winter water temperature in the shallow Suez Bay is cooler and algal uptake rates are lower than summer uptake rates.

In assessing the existing water quality of Suez Bay, there are major pollutant sources other than present wastewater discharges from El Saal Drain. First, oil pollution has been recognized as a serious problem for many years. Casual observation during the most recent field surveys confirms that surface slicks exist in patches scattered throughout the northern parts of the bay at all times. The specific sources for the oil are unknown but may be from refinery wastewater, from spillage during loading operations at the oil berth in the middle of the bay, or from vessels either moored in the bay or transiting the bay en route to or from the Suez Canal. El Saal Drain from the railroad bridge (located just upstream of the Coastal Road bridge) to the outlet was clearly contaminated by oil from an apparent pipeline break. Vegetation and floating debris along the drain were coated with oil, as was most of the shoreline around the El Saal Drain outlet and tending eastward. This oil clearly is an important source of contamination in and around El Saal Drain. Oil slicks have a mildly repressive effect on algal productivity and significantly reduce air-water oxygen exchange.

Second, the industrial facilities along the western and northern margins of the bay (including a power generating station, fertilizer plant, refineries and petroleum processing facilities, fishing marinas, and shipyards) may all contribute toxic wastes or nutrients to the overall pollutant loading in the bay. These may be added either via process water or wastewater streams, or from atmospheric fallout of particulates from stack emissions. Finally, the very heavy use of the bay by shipping may contribute toxic metals from antifoulant paints, as well as sewage wastes, oily wastewater, and general refuse. Anti-fouling paints may have an inhibitory effect on phytoplankton productivity as well as benthic biota.

3.3.2.3 Pollutant Loading

The correlation between measured flows in El Saal Drain and tidal elevation (predicted tide height at Port Tewfiq) appears quite good as shown below, considering there are only four data points.

Date	Time	Flow, m^3/day	Tide
28 November 1989	1700	128,450	+2.66'; 0.5 hr before LW
3 December 1989	1030	104,350	+3.44'; 2.0 hr after LW
5 December 1989	1434	74,000	+5.25'; 0.5 hr before HW
8 December 1989	0925	89,730	+3/61'; 1.5 hr after HW

It would appear that maximum flow out of El Saal Drain occurs near the time of low tide (LW), and that minimum flow occurs nearest the time of high tide (HW); values intermediate in time show corresponding intermediate flows. The overall average was 99,100 m^3/day, which is probably a reasonable estimate of daily flow adjusted for tidal pulsing.

Pollutant loadings to Suez Bay from the drain were calculated (Table 11) for a number of constituents and were compared to loads from the Suez WWTP. The WWTP loads were computed using flows (67,200 m^3/d) measured in November 1989 and raw wastewater constituent concentrations as measured by CMC; it assumes that there is no removal of constituents by the existing WWTP. The assumed concentrations are 280 mg/l BOD_5, 9.0 mg/l TP, and 40 mg/l TKN. TKN is a sum of organic and ammonia nitrogen. CMC measured only ammonia nitrogen in the raw wastewater, and found a value of 40 mg/l. Thus, TKN values used in the calculations in Table 11 may be low. Waste loading from El Saal Drain is based on the measured mean flow (99,100 m^3/d) and the mean values reported in Table 9.

Also reported in Table 11 is the calculated percent load in El Saal Drain that is attributable to wastewater. These data indicate that the primary source of nutrients to El Saal Drain is the WWTP. The potential underestimate of TKN in the wastewater means that the wastewater contribution of TKN to El Saal Drain is higher than the 73% calculated in Table 11. The data also show that there is a significant source of BOD_5 in addition to the WWTP. The significance of this is that the BOD_5 load to Suez Bay from El Saal Drain may not significantly change with an improved municipal WWTP or discharge of WWTP effluent to a submarine outfall. The presence of oil in El Saal Drain as well as solid wastes near the sample collection point may be major sources of the additional BOD_5 load.

The proposed WWTP treatment alternatives considered in this water quality analysis are primary treatment or Law 48 treatment. Although Law 48 effluent

Table 11. Waste Loading from El Saal Drain

	El Saal Load		WWTP Load		
Flow (m^3/d)	99,100		67,200		
	mg/l	kg/d	mg/l	kg/d	
BOD_5	747	74,000	280	18,000	(25%)
TP	4.0	400	9	600	(100%)
TKN	38	3,700	40[a]	2,700	(73%)

a: CMC data show 40 mg/l NH4-N in raw wastewater

261

is expected from the proposed WWTP, primary treatment is evaluated in this report as the lowest level of treatment (conservative case). We assume approximately 35% reduction in BOD_5 with primary treatment, and also assume TKN concentration of 40 mg/l. Using the CMC year 2005 design flow of 130,000 m^3/day, the constituent loads are given below for existing and the proposed treatment levels:

	Existing	Primary		Law 48	
Constituent	kg/d	mg/l	kg/d	mg/l	kg/d
BOD_5	18,000	180	23,400	60	7,800
TP	600	7	910	7	910
TKN	2,700	40	5,200	26.5	3,400

These calculations show that Law 48 provides a reduction in total BOD_5 loading by wastewater discharge to Suez Bay.

The constituent loads from the El Saal Drain do not represent the total input to Suez Bay as there are other sources such as the fertilizer plant and various refineries. Because no data were available on the magnitude of these inputs, the modeling did not account for the unknown industrial inputs.

3.3.2.4 Sediment Microbiology

Bacteriological analyses were done on surface waters and seafloor sediments collected at Stations 1 through 6 and 20 through 34 (Figure 2); surface waters were analyzed for total and fecal coliforms, while sediments were analyzed for long-lived amoebic cysts indicative of sewage contamination.

Surface waters from every station tested positive for both fecal and total coliforms (Dames & Moore, 1990). Sources for these bacteria are indeterminate and may have derived from permanent point sources (such as El Saal Drain or other surface drains) or from transient sources (primarily moored ships).

The distribution of amoebic cysts in sediments showed a somewhat clearer pattern of positive test with distance from El Saal Drain (Figure 12). The persistent northward flow of subsurface waters seen at Station 5 may account for the northward deflection of the isopleths directly offshore of the drain. The amoebic cyst data, in combination with current data collected as part of the study, suggest that a majority of the settleable fractions of the wastewater discharge from El Saal Drain move eastward, toward the new harbor area.

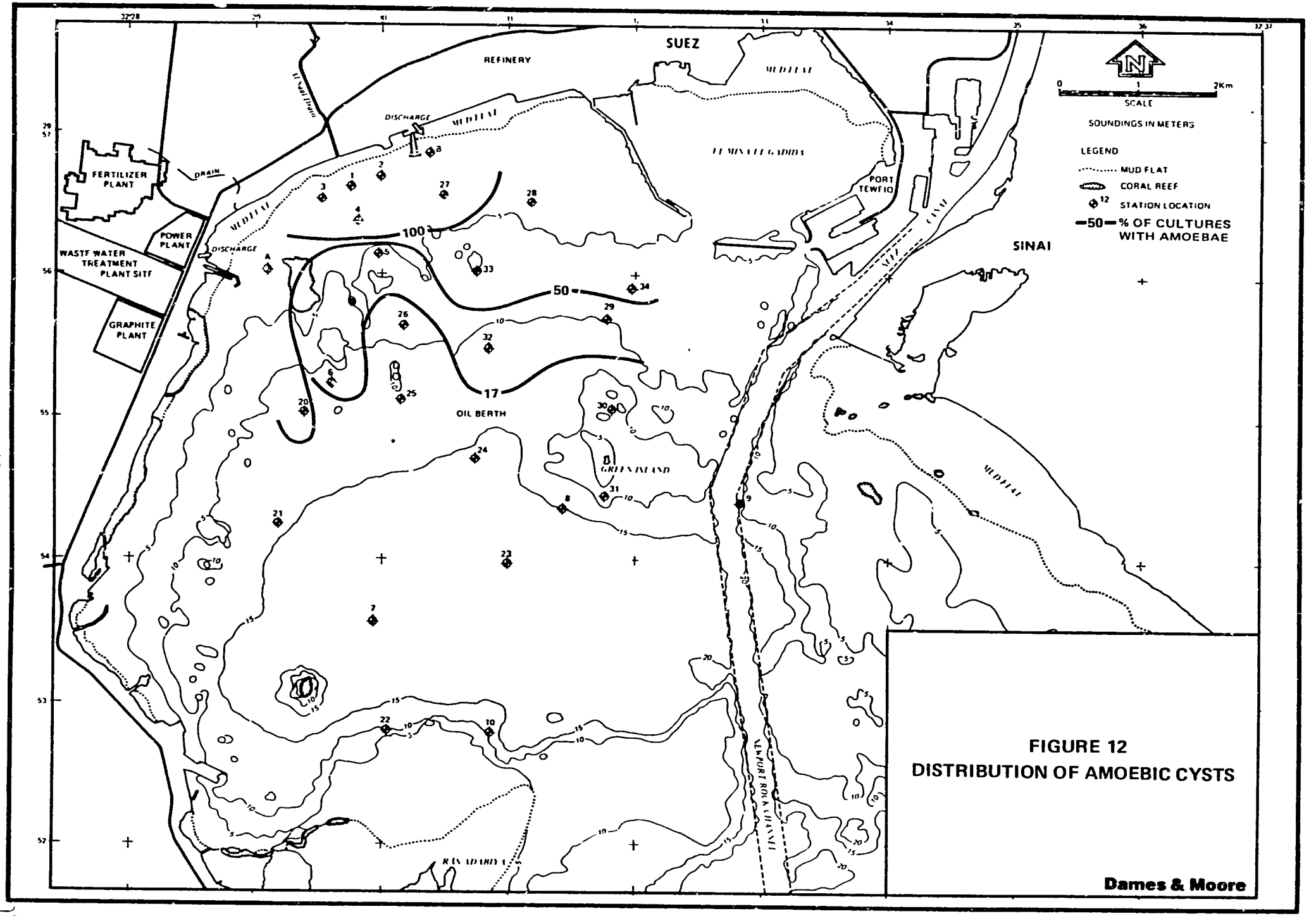


FIGURE 12
DISTRIBUTION OF AMOEBIC CYSTS

3.3.2.5 Water Quality Modeling

3.3.2.5.1 PLUME

The PLUME variant UDKHDEN was run with combinations of discharge depths, number of ports, and current and density profiles as shown in Table 12. All model runs used an outfall discharge volume of 1.504 m^3/sec. Currents were input as zero, as constant with depth using values shown, or with depth-dependent values measured in the immediate vicinity and the density profiles appropriate for the 10 m depth. In all cases, port diameter was assumed at 0.15 m, port spacing at 5.0 m, and discharge angle at 30 degrees above horizontal. Other arrangements could have been selected; these were used consistently in this analysis for comparative purposes. Effluent salinity was assumed to be 2.0 ppt, except Case 9 where it was assumed to measure 5 ppt. The salinity value of 2 ppt is based on chloride concentration of approximately 1300 mg/l in raw sewage. A salinity value of 5 ppt is based on total dissolved solids concentration of approximately 5000 mg/l in raw wastewater. Temperature was assumed to be 20°C.

The dilution ratio of treated wastewater at a 5 m depth ranges from 24:1 to 101:1 (Table 12). Lower dilution ratios are predicted for slack current in Suez Bay, while the higher dilution ratios are predicted for more typically expected currents. The dilution ratio for a 10 m deep outfall with similar input parameters ranges from 64:1 to 195:1. The lower dilution ratio is predicted for slack current conditions, while the higher dilution ratio is predicted for a typical current condition with 40 ports. A reduction in current speed at the surface (Case 8) produces a smaller dilution for a 10-m deep outfall, albeit still appreciable at 122:1. Case 9 was run with conditions identical to Case 8, except an effluent salinity of 5 ppt was used. The result indicates that an increase in salinity from 2 ppt to 5 ppt results in only a marginal change in dilution.

The plume will be approximately 6 m wide for a 5 m deep outfall and 8.5 m wide for a 10 m deep outfall; in both cases it will be 200 m long when it reaches the surface. Current measurements indicate that the plume will generally proceed in a southeasterly direction away from shore.

In order to provide a measure of the degree of dilution needed to protect human health, an analysis of fecal coliform dilution and die-off was conducted for both the 5 m and 10 m deep outfalls. The following assumptions were made:

- Fecal coliform die-off was first order with a decay rate typical for marine waters. The first order decay formula is $N = N_o\exp(-K_B t)$. The decay rate was calculated according to the formula (Thomann and Mueller, 1987):

Table 12. PLUME Model Results

Case	Discharge Depth, m	No. of Ports	Suez Bay Ambient Current m/sec	Time for Plume to Reach Surface, sec	Dilution Ratio
4	5	40	0	8	24:1
7	5	20	0.05	11	45:1
5	5	40	0.05	13	62:1
6	5	40	0.10	18	101:1
1	10	40	0	22	64:1
3	10	20	0.02-0.2	24	116:1
2	10	40	0.02-0.2	39	195:1
8	10	40	0.01-0.1	26	122:1
9[a]	10	40	0.01-0.1	27	121:1

a: 5ppt salinity instead of 2ppt

$K_B = [0.8 + 0.006(\%\ \text{seawater})]1.07^{(T-20)}$ where:

N_o = initial fecal coliform level, organisms/100 ml
N = fecal coliform level at time t, days
K_B = decay rate.

- The concentration of fecal coliform bacteria in raw wastewater was assumed to be 10,000,000 organisms per 100 ml, and a 96% die-off rate was assumed to occur in the WWTP. This rate is conservative, as the die-off within waste stabilization WWTP's ranges from 96% for a one-cell system to 99% for a three-cell system (Thomann and Mueller, 1987).

- The WWTP effluent was not chlorinated.

- The current was on-shore with an average velocity of 0.1 m/sec. This condition was not observed during the field measurements, and is assumed as a worst-case condition.

Based on these assumptions the end-of-pipe fecal coliform level would be 400,000 organisms/100 ml, and the fecal coliform concentrations as the plume reaches the water surface would be 4,000 organisms/100 ml for the 5 m deep outfall and 2,100 organisms/100 ml for a 10 m deep outfall. These values are within 5,000 organisms/100 ml established as a criterion by Law 48.

The plume from a 5 m deep outfall would reach the shore in 1.7 hours with a die-off rate of 9%, and the plume from a 10 m deep outfall would reach the shore in 4.2 hours with a die-off rate of 22%. The discharge from a 5 m deep outfall with an on-shore current of 10 cm/sec would result in a higher concentration of bacteria (3,950 organisms/100 ml) in the nearshore environment, compared to a discharge from a 10 m deep outfall which would result in a concentration of 1,770 organisms/100 ml in the nearshore environment. Discharge from El Saal Drain would produce 400,000 organisms/100 ml at the outlet to Suez Bay.

This analysis demonstrates that the discharge to a 10 m deep outfall would have lower public health effects than a 5 m deep outfall or discharge to El Saal Drain. The actual dilution achieved, however, could be modified in an important way by modifying the specifications for the diffuser.

3.3.2.5.2 WASP4

There are several elementary observations and calculations that can be made which illustrate the general magnitude of impact of the wastewater discharge upon Suez Bay and which should be considered in applying WASP4 to Suez Bay. First of all, the volume of the discharge in relation to the volume of the bay is small. The current daily discharge volume from El Saal Drain is 99,100 m^3/d, and the volume of the

discharge in relation to the volume of the bay is small. The current daily discharge volume from El Saal Drain is 99,100 m^3/d and the volume of the bay is 771 x 10^6 m^3. The flushing rate of the bay has been estimated to be 50 days (Pirnie-Harris International 1979), which translates to a daily outflow from Suez Bay to the Gulf of Suez of 15.4 x 10^6 m^3/day, 155 times the daily inflow from El Saal Drain. The dilution available in the nearshore environment in the vicinity of El Saal Drain is also substantial. The BOD_5 concentration in the El Saal Drain averaged 747 mg/l, while the average concentration in the upper meter of water at Station 1 was 12.2 mg/l. The dilutions for other constituents were less than the dilution for BOD_5, most likely due to the fact that BOD is a non-conservative substance. The BOD data indicate a dilution ratio of 61:1, whereas the TP data indicate a dilution ratio of 9:1.

The following assumptions were made in applying WASP4 to Suez Bay:

- The DYNHYD4 component of the model was not appropriate for describing hydrodynamic conditions in Suez Bay since two-layer flow was observed in the November-December field studies. Accordingly, flow patterns were not supplied by DYNHYD4 but were directly input to EUTRO4 using measured and extrapolated current velocities. For calibration to existing conditions, the flow pattern originating from the El Saal Drain as outlined by the field data is presented in Figure 13. The effect of dilution from Suez Bay flows was simulated by an assumed on-shore bottom layer with an average velocity of 1 cm/sec. The thickness of the bottom layer was assumed to be 1 meter. These assumptions result in an approximate dilution of 50:1, which is in the range of dilution rates calculated from constituent concentrations in Suez Bay at Station 1.

- Settling was assumed to occur for organic phosphorus and nitrogen, BOD, and phytoplankton.

- Wind was assumed to be a constant velocity of 2.5 m/sec based on the wind data measured during the November-December survey period.

- The model was run in a steady state mode. Accordingly, the model does not predict time-variable water quality changes in Suez Bay. The concentrations predicted by the model, therefore, should not be considered as absolutely correct.

- The model was calibrated to existing conditions for November 1989, and was then used to predict future conditions with primary or Law 48 effluent.

The model was calibrated to existing conditions by varying several parameters. Dr. Wu-Seng Lung of the University of Virginia played the key role in model calibration. The key parameters that were varied during the calibration include: the

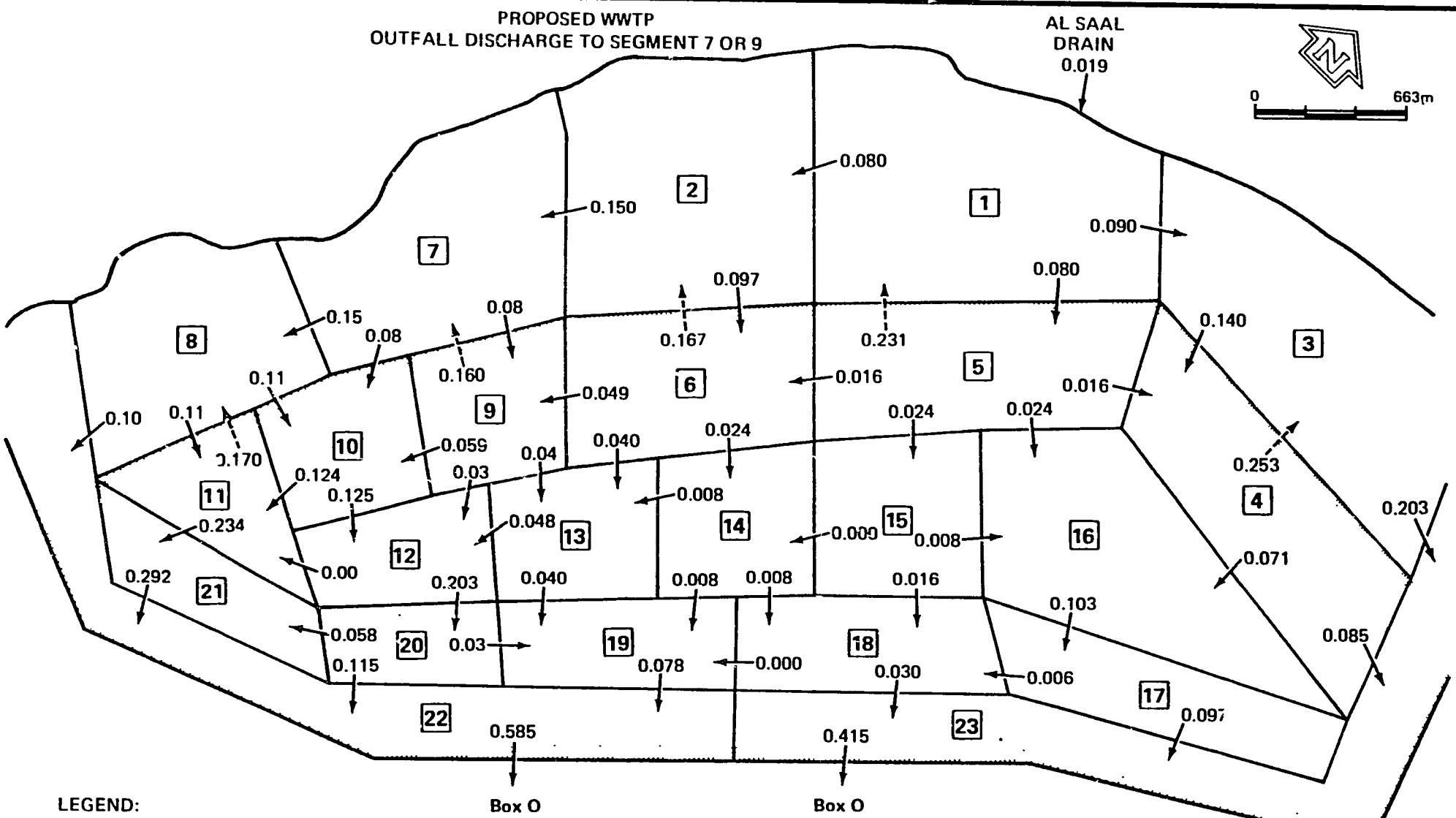


FIGURE 13
FLOW PATTERN FOR EUTRO4 MODEL OF SUEZ BAY

dispersion coefficient, algal settling rate, carbon to chlorophyll a ratio, and BOD decay rate. In the initial model runs, the dispersion coefficient (130.5 m^2/sec) and the algal settling rate (4.0 m/d) were high. Dispersion was reduced to 30 m^2/sec and algal settling to 0.5 m/d. The carbon to chlorophyll a ratio was initially set at 30:1, but was subsequently increased to 60:1, based on data suggesting that there are higher ratios in high salinity marine waters (Parsons et al. 1984). The BOD decay rate was initially set to 0.5/d, but this resulted in DO levels in the nearshore model segment (Figure 13) that did not conform to observed data. The BOD decay rate was reduced to 0.23/d. Average daily solar radiation levels were varied between 250-350 langleys/d; however, this parameter did not substantially affect model output. The model results for calibration to existing conditions are presented in Table 13.

It should be noted that the 280 mg/l BOD_5 concentration reported by CMC for raw wastewater is from an uninhibited BOD_5 test. An uninhibited BOD_5 is slightly greater than an inhibited carbonaceous BOD_5 due to a small amount of nitrification which occurs in an uninhibited BOD test. The WASP4 modeling requires an ultimate carbonaceous BOD, which is generally considered to be 1.55 times the 5-day carbonaceous BOD (Bowie et al. 1985). In the WASP4 modeling discussed in this report, the ultimate BOD_5 value used is 1.55 times the uninhibited BOD_5. Accordingly, there is a slight overestimate of BOD loading in the WASP4 modeling because it includes nitrogenous oxygen demand. This overestimate is believed to be subject of only small concern because there are most likely numerous other unmonitored BOD sources to Suez Bay that have not been included in this modeling.

The model significantly overpredicts BOD concentration in Suez Bay and underpredicts DO, compared to observed values (Table 13). This indicates that BOD is lost from Suez Bay in some manner that the model does not represent. The interaction of nutrients and chlorophyll a is fairly well represented by the model. The measured data indicate relatively high concentrations of nutrients while the chlorophyll a levels remained low. The model predicts slightly lower nutrient concentrations than observed; however, the predicted chlorophyll a values are relatively close to observed values.

Nutrient inputs from El Saal Drain were arbitrarily reduced by 90% in the input file CALIBEX3 in order to determine the response of chlorophyll a to a nutrient load reduction. The model predicts similar chlorophyll a value for a 90% nutrient load reduction scenario as for existing conditions.

Detailed examination of the output for CALIBEX2 (Dames & Moore, 1990) indicates that algal productivity in Suez Bay is limited by light. The output data indicate that if light did not limit phytoplankton productivity, the most limiting nutrient would be nitrogen. The reason for this disagreement with the nutrient ratio analyses in Section 3.3.2.2 is not known. The 90% reduction in nutrient loading modeled by CALIBEX3 and its lack of effect on chlorophyll a suggests that the most important factor to consider between treatment alternatives is the effect of BOD on DO in Suez

Table 13. Calibration of November WASP4 Model

	PARAMETER							
	BOD mg/l	DO mg/l	PO4-P mg/l	OrgP mg/l	OrgN mg/l	NH3 mg/l	NO3 mg/l	ChlA ug/l
Nov. 89 Sta. 1-4[a]	8.0	5.7	0.11	0.18	1.75	0.55	0.05	2.7
Sta. 6	5.8	6.7	0.04	0.04	0.51	0.52	0.04	1.2
Input File Segment								
CALIBEX2 1[b]	32.5	3.5	0.09	0.08	1.54	0.22	0.06	9.8
CALIBEX2 9	4.6	5.4	0.03	0.03	0.50	0.10	0.05	9.0
CALIBEX3[c] 1	3.9	6.1	0.01	0.03	0.50	0.07	0.05	9.5
9	1.1	6.3	0.01	0.02	0.36	0.07	0.05	8.9

a: Average of Measured Values
b: Segment 1 includes Stations 1-4
c: CALIBEX3 has nutrient inputs reduced by 90%

Bay. Thus, the discrepancy in interpretation of which nutrient may be most limiting may be unimportant.

Table 14 presents model results for effects of alternative treatment and discharge scenarios. As expected, there is little difference between the scenarios for chlorophyll a. Furthermore, there is little change in chlorophyll a over existing conditions. Nutrient conditions for discharge at El Saal Drain are not substantially different from the modeled existing condition. With a submarine outfall, nutrient concentrations rise in model Segments 7 and 9 (Figure 13), and remain unchanged in Segments 1 and 5.

DO concentrations for various discharge locations and treatment levels are presented in Table 15. There are three major scenarios in Table 15 that are not included in Table 14. These are:

- o primary effluent discharged at a 10-m deep outfall;
- o Law 48 effluent discharged at a 10-m deep outfall; and
- o primary effluent discharged to a 10-m deep outfall, assuming no industrial discharge from El Saal Drain.

Discharge of a primary effluent to El Saal Drain would result in lower DO concentrations compared to model results for existing conditions. A Law 48 effluent would increase DO concentration. Discharge of either primary or Law 48 effluent to either a 5-m or 10-m deep outfall is predicted to produce lower DO concentrations in all segments listed in Table 15. The surprising result is the reduced DO levels in Segments 1 and 5 (nearest El Saal Drain) with termination of WWTP discharge to El Saal Drain. This effect is likely caused by the surprisingly high BOD values now observed in El Saal Drain and the effect of reduced flows in the nearshore zone with removal of the WWTP flows.

Since there is some uncertainty regarding the source and magnitude of BOD loading in El Saal Drain that is not attributable to the WWTP, a scenario was run assuming a primary discharge via outfall and no industrial BOD or nitrogen loads in El Saal Drain (Table 15). The results are described further in Dames & Moore (1990) in the PRIMNIL file. If the non-WWTP (i.e., industrial loading) is terminated, there will be a significant increase in DO in Segments 1, 5, 7, and 9. This finding is consistent with BOD loading calculations in Section 3.3.1.3, where 75% of the BOD load in El Saal Drain is expected to be derived from a source other than the WWTP.

Overall, a discharge of Law 48 effluent to El Saal Drain will have a smaller area of impact than a submarine outfall, assuming that there is a continued high level of non-WWTP BOD loading. If the industrial load is eliminated, a submarine outfall will not have an adverse impact on water quality in Suez Bay.

Table 14. November WASP4 Model Results for Alternative Treatment and Discharge Scenarios

SCENARIOS

Scenario		BOD mg/l	DO mg/l	PO4 mg/l	OrgP mg/l	OrgN mg/l	NH3 mg/l	NO3 mg/l	Chla ug/l
Primary, El Saal Discharge	1	35.0	3.2	0.17	0.14	2.41	0.34	0.07	10.0
	5	18.8	3.9	0.11	0.09	1.45	0.24	0.06	9.8
	7	5.3	5.2	0.05	0.04	0.64	0.13	0.06	9.3
	9	4.9	5.3	0.04	0.04	0.62	0.12	0.06	9.1
Law 48, El Saal Discharge	1	18.3	4.82	0.17	0.14	1.66	0.30	0.43	10.0
	5	10.0	5.16	0.10	0.09	1.05	0.21	0.27	9.8
	7	3.1	5.79	0.05	0.04	0.54	0.12	0.12	9.4
	9	2.9	5.83	0.04	0.04	0.52	0.11	0.11	9.1
Primary, 5m Outfall	1	60.7	1.27	0.05	0.05	2.15	0.38	0.07	10.1
	5	32.9	2.19	0.04	0.04	1.36	0.27	0.06	9.9
	7	17.5	3.84	0.15	0.14	1.44	0.28	0.06	9.4
	9	12.0	4.06	0.09	0.08	0.98	0.20	0.06	9.2
Law 48, 5m Outfall	1	59.5	1.45	0.05	0.05	2.12	0.37	0.15	10.1
	5	31.9	2.37	0.04	0.04	1.34	0.26	0.14	10.0
	7	11.4	4.3	0.15	0.14	1.31	0.28	0.39	9.5
	9	9.1	4.4	0.09	0.08	0.91	0.20	0.23	9.2

Table 15. Predicted DO for Model Scenarios

	SEGMENT			
	1	5	7	9
Existing Conditions[a]	3.5	4.1	5.3	5.4
Primary, El Saal Discharge	3.2	3.9	5.2	5.3
Law 48, El Saal Discharge	4.8	5.2	5.8	5.8
Primary, 5 m Outfall	1.3	2.2	3.8	4.1
Law 48, 5 m Outfall	1.5	2.4	4.3	4.4
Primary, 5 m Outfall, No IL[b]	6.0	6.1	5.8	5.9
Primary, 10 m Outfall	1.4	2.2	3.9	4.1
Law 48, 10 m Outfall	1.5	2.4	4.3	4.5

a: DO in mg/l
b: IL = Industrial Wasteload from El Saal Drain.

4.0 CONCLUSIONS

4.1 Circulation in Northwestern Suez Bay

Flow from the El Saal Drain appears to be pulsed, and is correlated with tidal elevation in the nearshore receiving waters. When tides are high, outflow as measured at the Coastal Road bridge 500 m upstream from the outlet to Suez Bay is diminished; when tides are low, outflow increases.

Nearshore waters exhibit a two-layered flow pattern, with surface water (<1 m) generally displaced southward by dominant north winds. Subsurface waters are drawn northward to replace the surface waters moving offshore. Superimposed on that pattern is a small easterly residual current. The El Saal Drain discharge spreads out over the surface of the highly saline bay waters and forms a relatively fresh layer of water that thins with increasing distance from the outlet. The lens is visually discernible by its high concentration of particulate matter, and was observable up to 2 km south of the outlet.

There is some suggestion of migrating eddies in the northern part of the bay, based primarily on the progressive change in current directions (generally clockwise) seen at Station 5 (Figure 3, especially 19 and 26 November and 10 December), but the evidence is not strong. Remote imagery would be necessary to recognize migratory or stationary eddies.

4.2 Existing Water Quality

Chlorophyll a and BOD concentrations for Suez Bay in November-December were similar to those observed in July 1989, with the exception of stations nearshore to the El Saal Drain. The November-December sampling in the nearshore demonstrated that the El Saal Drain is having an impact on Suez Bay. Concentrations of nutrients were higher in November-December than in July, 1989. The sampling at Station 1 in November-December, 1989 indicated that there are elevated concentrations of BOD, fecal coliforms, and nutrients when compared to other stations. The concentrations for TP, phosphate, chlorophyll a were generally higher at Stations 2 to 4 than at Stations 5 and 6. Stations 5 and 6 had higher levels of ammonia, nitrate, and silica.

Pollutant inputs to Suez Bay from the El Saal Drain were high. The data indicate that the WWTP contributes most of the nitrogen and all of the phosphorus loading from El Saal Drain to Suez Bay. BOD inputs from the WWTP constitute only 25% of the overall BOD input from El Saal Drain to Suez Bay. Much of the non-WWTP BOD may be produced by the residual oil contamination from an upstream spill and large quantities of solid waste trapped on the water surface of El Saal Drain near the Coastal Road bridge.

Data from current meters and amoebic cysts in Suez Bay sediments indicate that the plume from the existing discharge from El Saal Drain flows more to the east than to the west.

4.3 Projected Water Quality for El Saal Drain Discharge

WASP4 modeling indicates that an El Saal Drain discharge would have a smaller area of impact that a marine outfall. This assumes, however, that high BOD loading to El Saal Drain remains from sources other than the WWTP. Furthermore, the impact zone would remain in the nearshore zone, with potentially high levels of coliform bacteria in the poorly diluted plume. If the non-WWTP source of BOD were eliminated from El Saal Drain, a submarine outfall would provide much improved water quality in the nearshore zone.

Model results indicate that increased nutrient loading to El Saal Drain from either a primary or Law 48 effluent will not increase chlorophyll a levels in the nearshore environment of Suez Bay.

4.4 Projected Water Quality for Submarine Discharge

The PLUME modeling indicates that the 5 m deep outfall discharging 600 m offshore will not dilute fecal coliform levels to below 200 organisms/100 at the shoreline. The 10 meter deep outfall discharging 1500 meters off-shore also will not dilute fecal coliforms to below 200 organisms/100 ml at the shoreline, but there will be a much larger reduction compared to the 5-m deep outfall or discharge via El Saal Drain. Modifications to the diffuser design may further reduce fecal coliform concentrations. The criterion of 200 organisms/100 ml is used in the United States if the receiving water is designated for use by swimmers. Egyptian Law 48 establishes a criterion of 5,000 organisms/100 ml, and is probably more applicable to Suez Bay. If the raw wastewater fecal coliform counts are higher than the values assumed in this analysis, or if constraints on diffuser design and length prevent higher initial dilution, then chlorination might be necessary if it is determined that these levels of contamination are unacceptable.

A further consideration for siting of a submarine outfall is the proximity of the proposed discharge location to the Ataqa marine research laboratory of the Red Sea and Suez Canal Branch of the National Institute of Oceanography and Fisheries. The laboratory proposed to operate a seawater circulation system that supplies running seawater to their laboratory facilities. The water intake for that system has not yet been designed. It is likely to be located near the laboratory, and therefore will lie within a few hundred meters of the proposed 5 m submarine outfall discharge site. A 10-m deep outfall will be located about 1.5 km from shore.

5.0 RECOMMENDATIONS

A 10 m outfall is preferred because it offers the greatest protection to public health and is in sufficiently shallow water to be outside of ship berthing areas. Additional diffuser design analyses are needed to determine whether greater reduction of fecal coliform levels can be provided.

A Law 48 effluent will result in higher DO levels in Suez Bay, and would be the environmentally preferred treatment level.

REFERENCES

Ambrose, R.B., Jr., T.A. Wool, J.P. Connolly, and R.W Schanz. 1988. WASP4, A Hydrodynamic and Water Quality Model - Model Theory, User's Manual, and Programmer's Guide. EPA/600/3-87/039, Environmental Research Laboratory, U.S. Environmental Protection Agency, Athens, GA.

Baldwin, M.F., D. Ferguson, K.A. Saterson, and I.E. Wallen. 1988. The Biological Resources of the Arab Republic of Egypt Status and Recommended Conservation Needs. Prep. for USAID/Cairo, Office of Science and Technology.

Bowie, G.L., W.B. Mills, D.B. Porcella, C.L. Campbell, J.R. Pagenkopf, G.L. Rupp, K.M. Johnson, P.W.H. Chan, S.A. Gherini, and C.E. Chamberlin. 1985. Rates, Constants, and Kinetics Formulations in Surface Water Quality Modeling (2nd Ed.). EPA/600/3-85/040. Environmental Research Laboratory, US Environmental Protection Agency, Athens, GA. 455 pp.

Johnston, R. 1976. Marine Pollution. Academic Press, New York.

Lorenzen, C.J. 1972. Extinction of light in the ocean by phytoplankton. J. Cons. int. Explor. Mer 34:262-267.

Marine Environmental Services, Inc. 1979. Oceanographic Studies, Suez. Unpubl. report submitted to Firnie-Harris International and Ministry of Housing and Reconstruction, Arab Republic of Egypt. June 1979.

Meshal, A.H. 1967. A Physical Study of Water Pollution in Suez Bay (Hydrography of Suez Bay). M.Sc. Thesis, Faculty of Science, University of Cairo, Egypt. 109 pp.

Muellenhoff, W.P., A.M. Soldate, Jr., D.J. Baumgartner, M.D. Schuldt, L.R. Davis, and W.E. Frick. 1985. Initial Mixing Characteristics of Municipal Ocean Discharges: Vol. I. Procedures and Applications, and Vol. II. Computer Programs. EPA/600/3-85/073, Environmental Research Laboratory, U.S. Environmental Protection Agency, Narragansett, RI.

Officer, C.B. and J.H. Ryther. 1977. Secondary sewage treatment versus ocean outfalls: An assessment. Science 197:1056 - 1060.

Parsons, T.R., M. Takahashi, and B. Hargrave. 1984. Biological Oceanographic Processes. Pergamon Press, Oxford, England.

Pirnie-Harris International, Inc. 1979. Suez Wastewater Facilities Master Plan Report, Volume 2 - Technical Report, Appendix F - Oceanographic Studies, Appendix G - Water Quality Modelling, and Special Report No. 1 - Oceanographic Studies. Prep. for Ministry of Development and New Communities, Arab Republic of Egypt.

Tait, R.V. and R.S. De Santo. 1972. Elements of Marine Ecology. Springer-Verlag, New York. 327 pp.

Thomann, R.V. and J.A. Mueller. 1987. Principals of Surface Water Quality Modeling and Control. Harper & Row, New York. 644 pp.

U.S. National Ocean Survey. 1988. Tide Tables, High and Low Water Predictions, Western Pacific Ocean and Indian Ocean, 1989. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Rockville, MD.

APPENDIX C
FAUNA OF THE SUEZ AREA

Reptiles and Amphibians

The following are the common reptiles and amphibians of Suez and its environs, with notes about their habitat requirements (sources: Anderson 1898; Marx 1968; and Baha el Din, unpubl. data).

Turkish gecko *(Hemidactylus turcicus).* Usually found in houses where it feeds on insects, but will also live in rocky areas.

Natterer's gecko *(Tropiocolotes steudneri).* This species inhabits flat open deserts with scattered vegetation where it hides under rocks. It has been recorded in the vicinity of the proposed treatment plant location.

Ptychodactylus hasselquisti. A rock-dwelling species which is found commonly on the Ataqa plateau.

Pale agama *(Agama mutabilis).* This lizard species is an uncommon inhabitant of flat sparsely vegetated stony desert. It has been recorded frequently on the coastal plain south of Suez.

Sinai agama *(Agama sinaita).* A rock-dwelling species inhabiting the steep limestone hills of the Ataqa plateau.

Egyptian dabb-lizard *(Uromastix aegyptius).* This large herbivorous lizard (up to 60 cm in length) is common in the well-vegetated wadis draining the Ataqa plateau, but it will also inhabit stony plains if there is sufficient vegetation.

Bosc's lizard *(Acanthodactylus boskianus).* This is probably the most numerous reptile in Egypt. It inhabits a variety of habitats ranging from salt marshes to rocky desert. The species has been recorded at the site of the proposed treatment plant and its environs.

Small-spotted lizard *(Mesalina guttulata).* A widespread rock-dwelling species which is often found in areas completely devoid of vegetation. Sometimes found at high altitudes, but is also found on the stony areas of the coastal plain south of Suez.

Eyed skink *(Chalcides ocellatus).* A sand-dwelling species, usually found near dry agricultural areas and in well vegetated wadis often near water. This species is one of Egypt's most common reptiles. At Suez it is mostly found in marginal desert north of the city.

Audouin's skink *(Sphenops sepsoides).* A characteristic species of the sand dune ecosystem. Although no extensive sand dunes are found near Suez, the species uses patches of loose sand in the wadis.

Schokari sand-snake *(Psammophis schokari).* Probably the most numerous and widespread snake in the Egyptian deserts. A diurnal snake which feeds mainly on lizards. Inhabits well vegetated wadis, but is also found in a variety of other habitats such as coastal salt marshes and rocky areas.

Clifford's snake *(Spalerosophis diadema).* Inhabits semi-deserts and well vegetated rocky areas usually close to fresh water sources.

Black cobra *(Walterinnesia aegyptia).* The rarest and one of the least known reptiles of the region. In Egypt this species is only known from the desert stretch between Suez and Cairo and from parts of southern Sinai. It inhabits well vegetated wadis and rocky areas where it usually takes shelter in rodent burrows, on which it feeds. Several examples of this species have been collected in the vicinity of the Ataqa plateau close to Suez.

Horned viper *(Cerastes cerastes).* One of the prominent and characteristic reptiles of the region. This viper lives in a variety of habitats, but it is especially attracted to sandy patches amidst rocky desert landscapes where some vegetation may occur.

Carpet viper *(Echis coloratus).* An uncommon inhabitant of rocky deserts, usually found at higher altitudes than *C. cerastes.* Often attracted to fresh water sources where it might pose some danger to humans, as its venom is one of the strongest known.

Reuss's toad *(Bufo regularis).* The most common and widespread amphibian in Egypt. At Suez it is found in agricultural land and gardens.

Green toad *(Bufo viridis).* A species adapted to desert life. At Suez it is found at the ecotone between desert and agricultural land and often at water sources in the desert.

Mascarene frog *(Rana mascareniensis).* Strictly confined to fresh water. At Suez it is found in agricultural land in canals and marshes north of the city.

Mammals

Following is a systematic list of the known mammals (except bats) of Suez, with notes on their ecology (sources: Osborn and Helmy, 1980: Baha el Din, unpubl. data).

House shrew *(Suncus murinus).* Only known from Suez in Egypt where it lives in houses and buildings. It has a much larger range outside Egypt.

Hare *(Lepus capensis).* Inhabits vegetated wadis and wadi mouths along the Gulf of Suez, where it hides amongst vegetation and in burrows during the day time.

Greater gerbil (*Gerbillus pyramidum*). A large gerbil which prefers well vegetated areas. At Suez it has been found in palm groves and near cultivation.

Lesser gerbil (*Gerbillus gerbillus*). A widespread inhabitant of the Egyptian deserts. Lives in sandy wadis where sand accumulates around bushes and shrubs.

Large North African dipodil (*Dipodillus campestris*). A widespread desert rodent. Usually inhabits rocky deserts and is less restricted to sandy situations.

Wagner's dipodil (*Dipodillus dasyurus*). Mainly inhabits rocky areas with scattered scrub.

Pigmy dipodil (*Dipodillus henleyi*). This small desert rodent lives in a variety of habitats including vegetated wadis, coastal marshes, cultivated areas, and among rocks.

Bushy tailed dipodil (*Sekeetamy calurus*). Strictly a rock-dwelling species known from the mountains of the Red Sea and South Sinai.

Silky jird (*Meriones crassus*). Found in vegetated wadis and coastal areas.

House rat (*Rattus rattus*). A common urban dweller.

House mouse (*Mus musculus*). A common urban dweller.

Egyptian spiny mouse (*Acomys cahirinus*). Occurs in two subspecies. The melanistic *A.c. cahirinus* is a widespread urban dweller, while several other desert subspecies are rock dwellers. At Suez both the nominate subspecies (which is found in the city), and *A.c. megalodus* (which lives on the Ataqa plateau) are found.

Golden spiny mouse (*Acomys russatus*). This diurnal rodent is strictly a rock-dweller which inhabits rocky hillsides and boulder-strewn wadis.

Bandicot rat (*Nesokia indica*). Found in cultivated areas around Suez (the type locality is Shallufa north of Suez). It is found in damp localities and at the borders of saline lakes.

Lesser jerboa (*Jaculus jaculus*). Lives in open sandy wadis.

Red fox (*Vulpes vulpes*). Lives in a variety of habitats ranging from well vegetated wadis and rocky desert to cultivated areas. In Suez it is largely found in the agricultural area and its border with the desert. An adult and two cubs were seen in 1981 in front of their den hidden amongst tamarix bushes at the existing wastewater treatment plant.

Rueppell's sand fox (*Vulpes rueppelli*). Smaller than *V. vulpes* and more adapted to desert life. It is found in a wide variety of desert habitats ranging from open sandy desert to mountainous and coastal deserts. At Suez it is most likely found on the Ataqa plateau

and the surrounding plain. Might be found in the environs of the proposed wastewater treatment plant site.

Egyptian mongoose *(Herpestes ichneumon)*. A widespread carnivore in the Nile Valley and Delta. It favors areas close to wetlands and often found near canals and wetlands. At Suez it has been found in the marshy areas north of the city.

Birds

This is a systematic list of the important and regularly recorded bird species of Suez and its environs. Abbreviations indicate the status of each bird: **RB** = Resident Breeder; **MB** = Migrant Breeder; **WV** = Winter Visitor; **M** = Migrant.

Species	Status
Great-crested grebe *Podiceps cristatus*	WV
Cormorant *Phalacrocorax carbo*	WV
White pelican *Pelecanus onocrotalus*	M
Dalmatian pelican *Pelecanus crispus*	M
Grey heron *Ardea cinerea*	M+WV
Purple heron *Ardea purpurea*	M
Little egret *Egretta garzetta*	M+WV
Cattle egret *Bubulcus ibis*	RB
Squacco heron *Ardeola ralloides*	M
Night heron *Nycticorax nycticorax*	M
Little bittern *Ixobrychus minutus*	M (RB?)
Spoonbill *Platalea leucorodia*	M
White stork *Ciconia ciconia*	M
Black stork *Ciconia nigra*	M
Glossy ibis *Plegadis falcinellus*	M
Greater flamingo *Phoenicopterus ruber*	M
Wigeon *Anas penelope*	M
Teal *Anas crecca*	M+WV
Gargany *Anas querquedula*	M
Pintail *Anas acuta*	M
Shoveler *Anas clypeata*	M
Tufted duck *Aythya fuligula*	M
Pochard *Aythya ferina*	M
Ferruginous duck *Aythya nyroca*	M
Osprey *Pandion haliaetus*	M
Black kite *Milvus migrans*	M
Sparrowhawk *Accipiter nisus*	M
Steppe buzzard *Buteo buteo vulpinus*	M
Long-legged buzzard *Buteo rufinus*	M (WV?)

Lesser spotted eagle *Aguila pomarina*	M
Steppe eagle *Aguila nipalensis*	M
Spotted eagle *Aguila clanga*	M
Imperial eagle *Aguila heliaca*	M
Booted eagle *Hieraetus pennatus*	M
Egyptian vulture *Neopheron percnopterus*	M
Marsh harrier *Circus aeruginosus*	M
Hen harrier *Circus cyaneus*	M
Barbary falcon *Falco pelegrinoides*	RB
Sooty falcon *Falco concolor*	MB
Kestrel *Falco tinnunculus*	RB+M
Quail *Coturnix coturnix*	M
Water rail *Rallus aquaticus*	WV (RB?)
Crane *Grus grus*	M
Moorhen *Gallinula chloropus*	RB+WV
Purple gallinule *Porphyrio porphyrio*	RB
Coot *Fulica atra*	M+WV
Painted snipe *Rostratula benghalensis*	RB
Oystercatcher *Haematopus ostralegus*	WV
Black-winged stilt *Himantopus himantopus*	M (RB?)
Avocet *Recurvirostra avosetta*	M
Little ringed plover *Charadrius dubius*	M
Ringed plover *Charadrius hiaticula*	WV+M
Kentish plover *Charadrius alexandrinus*	B+WV+M
Greater sand plover *Charadrius lechenaulti*	WV
Grey plover *Pluvialis squatarola*	WV+M
Spur-winged plover *Hoplopterus spinosus*	RB
Little stint *Calidris minuta*	WV+M
Dunlin *Calidris alpina*	WV+M
Curlew sandpiper *Calidris ferruginea*	M
Redshank *Tringa totanus*	WV+M
Greenshank *Tringa nebularia*	WV+M
Marsh sandpiper *Tringa stagnatilis*	M
Common sandpiper *Tringa hypoleucos*	WV+M
Green sandpiper *Tringa ochropus*	WV+M
Ruff *Philomachus pugnax*	M
Black-tailed godwit *Limosa limosa*	M
Bar-tailed godwit *Limosa lapponica*	M
Snipe *Gallinago gallinago*	WV+M
Cream-colored courser *Cursorius cursor*	M
Black-headed gull *Larus ridibundus*	WV+M
Gull-billed tern *Gelochelidon nilotica*	M
Whiskered tern *Chlidonias hybridus*	M
White-winged black tern *Chlidonias leucopterus*	M
Spotted sandgrouse *Pterocles senegallus*	RB

Rock dove *Columba livia*	RB
Stock dove *Columba oenas*	WV
Turtle dove *Streptopelia turtur*	M (MB?)
Collard dove *Streptopelia decaocto*	RB
Palm dove *Streptopelia senegalensis*	RB
Pallid swift *Apus pallidus*	M
Bee-eater *Merops apiaster*	M
Kingfisher *Alcedo atthis*	M
Hoopoe *Upupa epops*	RB
Hoopoe lark *Alaemon alaudipes*	RB
Short-toed lark *Calandrella cinerea*	M
Bimaculated lark *Melanocorypha bimaculata*	M
Skylark *Alauda arvensis*	M
Crested lark *Galerida cristata*	RB
Desert lark *Ammomanes deserti*	RB
Swallow *Hirundo rustica*	RB+M
Pale crage martin *Hirundo obsoleta*	RB
Sand martin *Riparia riparia*	RB+M
Meadow pipit *Anthus pratensis*	M
Red-throated pipit *Anthus cervinus*	WV
Tawny pipit *Anthus campestris*	M
White wagtail *Motacilla alba*	WV
Yellow wagtail *Motacilla flava*	M
Bulbul *Pycnonotus barbatus*	RB
Great grey shrike *Lanius excubitor*	RB
Red-backed shrike *Lanius collurio*	M
Reed warbler *Acrocephalus scirpaceus*	M
Clamorous reed warbler *Acrocephalus stentoreus*	RB
Fan-tailed warbler *Cisticola juncidis*	RB
Graceful warbler *Pirinia gracilis*	RB
Scrub warbler *Scotocerca inquieta*	RB
Olivaceous warbler *Hippolais pallida*	MB+M
Lesser whitethroat *Sylvia curruca*	M
Sardinian warbler *Sylvia melanocephala*	WV
Chiffchaff *Phylloscopus collybita*	WV
Wheatear *Oenanthe oenanthe*	M
Isabelline wheatear *Oenanthe isabellina*	WV
Mourning wheatear *Oenanthe lugens*	RB
White-crowned black wheatear *Oenanthe leucopyga*	RB
Redstart *Phoenicurus phoenicurus*	M
Bluethroat *Luscinia svecica*	WV+M
Goldfinch *Carduelis carduelis*	RB
Trumpeter finch *Rhodopechys obsoleta*	RB
Red avadavat *Amandava amandava*	RB
Linnet *Acanthis cannabina*	WV

Spanish sparrow *Passer hispaniolensis*	WV
House sparrow *Passer domesticus*	RB
Indian house crow *Corvus splendens*	RB
Brown-necked raven *Corvus ruficollis*	RB
Hooded crow *Corvus corone*	RB

APPENDIX D
CONSIDERATIONS FOR AGRICULTURAL REUSE OF EFFLUENT AT SUEZ

CONSIDERATIONS FOR AGRICULTURAL REUSE OF EFFLUENT AT SUEZ

1.0 General

If Egypt wishes to support agricultural reuse of effluent, it must first consider how the operation will be consistent with requirements of Law 93. If small farmers use Suez's treated effluent, then levels of treatment similar to those recommended by the World Health Organization (WHO) should be adopted (see Section 5.2.4.2). Larger corporate-style farm units may be capable of safely growing fruit trees with drip irrigation and fodder crops under sprinkle irrigation using effluent treated by the aerated lagoon system. This assumes the effluent is not disinfected, ie., with fecal coliform levels higher than the WHO's recommended 100 organisms/100 ml. For fodder crops, routine testing should be done to verify the absence of livestock-infecting helminths. The recommendations that follow for agricultural reuse at Suez assume these standards.

2.0 Effluent Salinity

Before Suez's treated effluent can be reused for agriculture, the TDS should be reduced to 1,500 mg/l or less. This can be achieved by fixing the leaks in the collection system, by desalination, or by mixing the effluent with less saline water. For the latter, the effluent would require diluting five-fold or more with the Sweetwater Canal's 700 ppm TDS in the water.

Infiltration does not appear to occur at a large number of points. Suez's wastewater collection system has three branch lines arriving separately at the present wastewater treatment plant. Conductivity testing at pump stations along two of the three lines finds values of 2000-3000 umhos, which corresponds to salinities of 2000 ppm or less (CMC 1989). Largescale infiltration may be localized to the remaining (untested) branch, or may occur below the pump stations on the force mains. Studies done in the late-1970s as part of the Wastewater Master Plan also suggest that infiltration occurs only in certain districts (Pirnie-Harris International 1979). If the saline groundwater infiltrates at a few rather than many points, it may be controllable at reasonable cost.

Desalination techniques and costs for lowering the salinity from 5000 ppm to 1500 ppm require study. Use of waste heat from the neighboring power plant or refinery gas byproducts are possibilities.

3.0 Farm Organization

Farm sizes in Egypt are among the world's smallest, averaging less than 5 feddans. Nevertheless, larger ventures of 100 to over 40,000 feddans can be found in the desert new lands areas. Tenure options for farming with Suez's treated wastewater span the range from a single large 5,000-plus feddan unit to 1,000 or more small farms. Smaller farms likely would be owned or leased by individual households; larger units by cooperatives, joint venture corporations, wholly Egyptian firms, or by the state. The latter includes not only public sector companies, but also the Army, which now operates several large new lands ventures south of Alexandria.

While equity favors small farmers, the health risks to small farmers and their families are higher than it would be for larger farming ventures. Furthermore, larger farms are more likely able to deal with the technical difficulty of using high salinity water on marginal soils.

4.0 Soils and Reclamation Sites

Suez Governorate's presently cropped area amounts to a narrow strip of land along the Sweetwater Canal to the north of the city. The Ministry of Agriculture and Land Reclamation is working to expand this area, particularly near the Nag el Hamdi Tunnel 10 km north of the city, and in the Sinai on the east bank of the Suez Canal. These areas will be irrigated using increased flows into the Sweetwater Canal, some of it drainwater diverted from the El Mahsama Drain near Ismailia. The Land Master Plan (Euroconsult-Pacer Consultants 1985) and the land reclamation planning authority (GARPAD) have not anticipated reuse of wastewater at Suez. GARPAD has not designated or reserved any sites for this purpose.

In essence, there are two options for reusing the wastewater in agriculture:

- o augment water supplies in the existing irrigation system north of the city for use on presently cropped lands or newly reclaimed lands; or

- o irrigate a single site (or a very few large sites in the same general area) solely with the wastewater.

The latter would avoid the health threat to small farmers and their families.

The most plausible site nearest the proposed new treatment plant is 8-10 km to the northeast, along the Cairo-Suez Road (Figure D-1). Soils in this area are for the most part flat, and less than 50 m elevation above the treatment plant; but they are

29

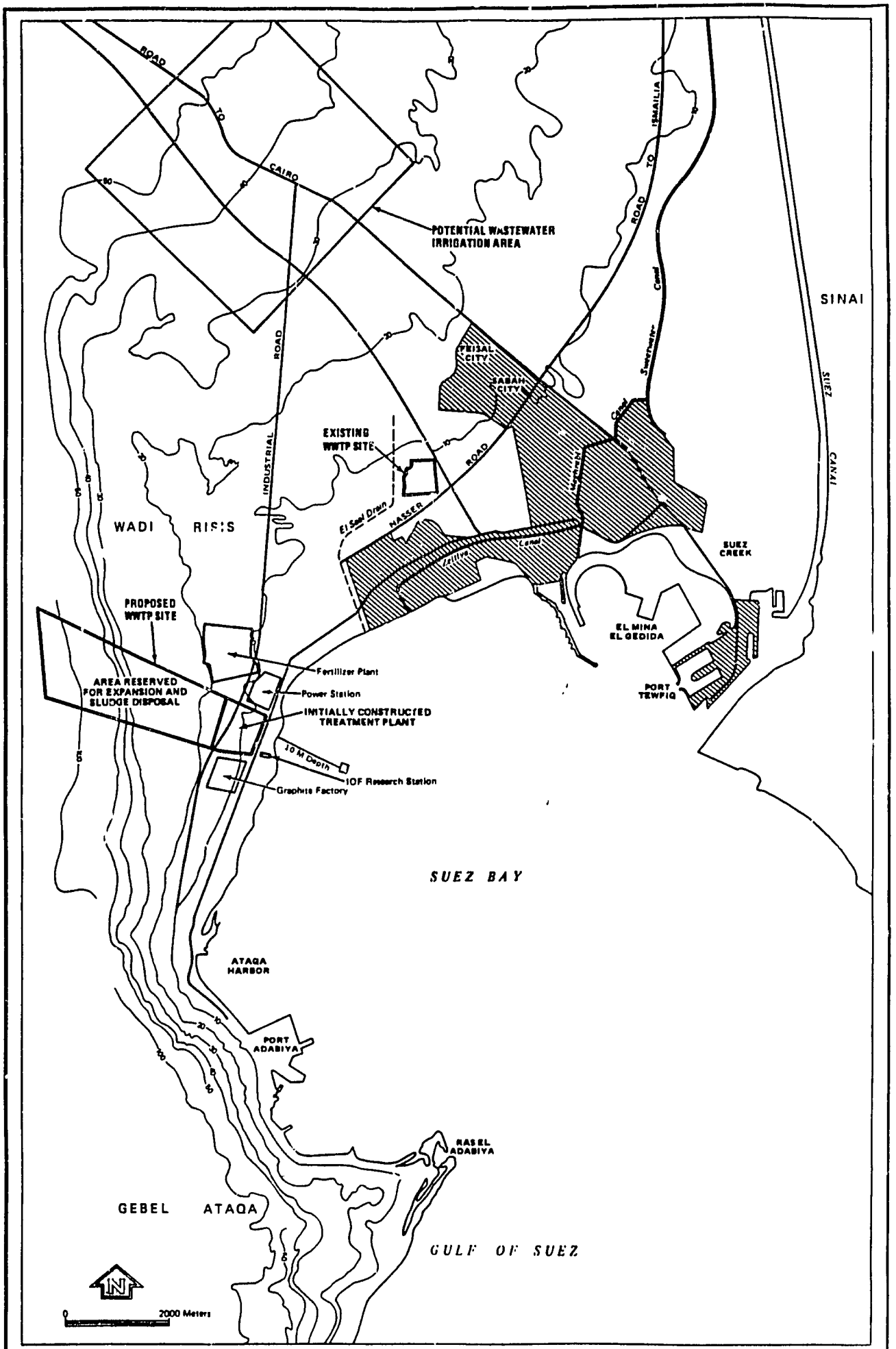


FIGURE D-1
POTENTIAL WASTEWATER IRRIGATION AREA

Dames & Moore

agronomically marginal by traditional standards. They are sands and loamy sands, saline before reclamation, low in nutrients and organic matter, but not high in calcium or gypsum. A gravelly outwash fan covers the base of nearby Gebel Ataqa.

The Land Master Plan places most of this area's soils in its Category V, i.e., coarse sands with low water holding capacity, and under 5% retention capacity (Euroconsult-Pacer Consultants 1985). The plan recommends irrigation of Category V soils only by drip and automatically controlled sprinkle, which can provide water daily during peak demand times. The Plan recommends cultivation of Category V soils in large units.

5.0 Crops and Farm Planning

With proper precautions, a variety of crops could be grown on the proposed site. Given that the soils will be prone to salinization and that considerable effort will be needed to produce an effluent with no more than 1,000-1,500 ppm TDS, saline-tolerant crops should be favored. Citrus and alfalfa are not particularly salt tolerant and likely would be marginal. Tomatoes, leafy vegetables, onions, potatoes, groundnuts, and the like may be cultivable, but too easily contaminated or not accepted by consumers. Below is a list of some possible crops:

Perennial Crops	Winter Crops	Summer Crops
Almond	Berseem	Cowpea
Pecan	Barley	Sudan Grass
Olive	Wheat	Sorghum
Date Palm	Broad Bean	Sunflower
Castor Bean	Lentils	Sesame
Jojoba		

The most plausible largescale farm operations are drip-irrigated orchards, or a dairy, such as at Salheyia, growing berseem, alfalfa (if suitable reduction in salinity can be achieved), and summer fodder crops under center pivot or lateral-move sprinklers.

6.0 Irrigable Area

Crop peak irrigation requirements determine the maximum irrigable area if there is no water storage. The irrigation requirement is the sum of crop evapotransporation, plus irrigation and conveyance losses. The latter should be small: 10-15% for drip and 15-20% for sprinkle. Peak irrigation requirements for the Suez area are roughly 60 m^3/ha per day for tree crops (except thirstier date palm) and 100 m^3/ha per day for field crops (Euroconsult-Pacer Consultants 1985). Thus, the forecast year-2005 flow of 130,000 m^3/day will irrigate 2,167 ha of orchard crops (4,767 feddans)

or 1,300 ha of field crops (2,360 feddans). At least double these areas could be cropped in the winter.

While the evaporative potential triples from winter to summer, urban wastewater flows are much more constant. Effluent-irrigated farms must either have the land and irrigation equipment to use the extra water in the cooler months, or the excess must be discharged-into the Bay. Whether the farming system varies the cropped area or not, some water storage capacity should be provided to smooth the meeting of continuously varying irrigation requirements. Even with storage, the wastewater treatment plant should maintain a backup means to discharge to the Bay.

7.0 Sludge Use

Health considerations for reusing the proposed treatment plant's sludge for agriculture have been covered elsewhere in this report (Chapter 5). Using the sludge on the proposed agricultural reuse site is logical given the poor soil quality. It may be possible to allow higher levels of pathogens in the sludge if it is used by larger ventures rather than small farms, since human contact with it should be easier to control.

8.0 Costs

Agricultural reuse of Suez's wastewater will cost a minimum of 2,500-5,000 LE/feddan. The main costs for this minimum amount include on-farm irrigation, trees, dairy cattle, and other farm equipment. Water lift should not exceed 30 m and conveyance not more than 10 km to the Cairo-Suez Road site. Costs to repair the sewage collection system to reduce infiltration or for desalination require further study.

9.0 Returns

Recent studies by the World Bank (1989) show that returns to drip- and sprinkle-irrigated farming on sandy soils can be high, particularly for orchard crops. The required lift at Suez of 30-40 m is moderate, since studies have found favorable returns for various cropping plans with lifts of up to 100 m. Shortening the time to production by using fast yielding dwarf and semi-dwarf trees, and by growing other annual crops in the early years strongly affect the returns to orchard crops.