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WATER POLLUTION IN SELECTED URBAN AREAS IN THE ESCWA REGION

(CASE-STUDIES OF DAMASCUS, GAZA AND JEDDAH)

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ABBREVIATIONS *(continued)*

UNESCO	United Nations Educational, Scientific and Cultural Organization
UNICEF	United Nations Children's Fund
WHO	World Health Organization
UNRWA	United Nations Relief and Works Agency for Palestine Refugees in the Near East

INTRODUCTION

1. *Basic considerations*

Over the past decade, the ESCWA region has witnessed an increased concentration of urban population in a few cities (primacy), which has become a growing phenomenon in the region. This trend towards urbanization is depicted in the projection of urban population in the ESCWA region presented in table 1. The rate of urban growth in the ESCWA member States is currently twice that in the developed countries and is expected to be three times as high in the year 2000. In ESCWA member countries, the largest city is usually the capital, which in some instances has expanded its role to such an extent that the capital city is in effect the country, as in Bahrain, Kuwait and Qatar. Even in densely populated countries such as Egypt, the capital exercises an extraordinary degree of dominance over life in the country. Such concentration in urbanization has resulted in major and acute environmental problems. In addition, the problems involved in large-scale industrialization, massive migration of rural populations to the primate cities and inadequacy of available shelter are compounded by inefficiency of the water and sewerage infrastructures owing to the increase in water demand.

Consequently, effective solutions to many emerging urban environmental problems should be found and achieved not only through the provision of financial resources, which might be wasted or misdirected, but through programmes based on the knowledge, practical experience, and the real needs of the community. It should be noted that the emphasis of Governments and local institutions in the past has been directed, for the most part, to the development and sound use of resources rather than the promotion of environmental quality. It was not until the past decade that Governments began to express serious concern about environmental protection. Most recently, public concern has begun to move from short-term pollution problems to the broader issues of the environmental impact of population growth and economic development and the sources of water pollution.

2. *Justification*

Following the 1992 United Nations Conference on Environment and Development, also known as the Earth Summit, which resulted in the issuance of Agenda 21, another conference, Habitat II, was convened on Human Settlements in June 1996. Both conferences stressed the urgent need to take measures to alleviate the environmental threats and pollution caused by the increased concentration of populations in cities, which are being recognized by authorities all over the world. Hence, sustainable development in the twenty-first century will, to a large degree, depend upon how cities, towns and villages everywhere interact with the environment and utilize natural resources, in particular water resources.

The ESCWA region is considered the driest region in the world; it is endowed with less than 1 per cent of the world's renewable fresh water. Per capita renewable resources are estimated at 1,250 cubic metres (cm) per year for the ESCWA region. Various studies predict that the population of the Middle East, especially the countries in the ESCWA region, could double again in 25-30 years, reducing per capita availability from 1,250 to 650 cm annually by the year 2025. In Yemen and in the West Bank and the Gaza Strip, it is already at 180 cm per year. Many countries and areas, such as Jordan, Yemen and the Gaza Strip, are abstracting groundwater at rates that far exceed the aquifer's renewable capacity (5, 6).

Agriculture is the main user of water resources in most ESCWA member countries (over 60%). Although in some areas, such as Gaza, the more efficient form of drip irrigation is practised, flood or canal irrigation, with resulting high rates of wastage and drainage, is the norm. Industrial use is still limited to less than 10% overall, but could increase rapidly with increased industrialization in some countries.

Most of these practices result in increasing pollution loads and affect downstream riparians; hence it is expected that water quality will become a more sensitive issue.

3. *Water pollution in the ESCWA region*

The problem of water scarcity is compounded and, in some countries, even overshadowed by the increasing problem of water quality in the region. According to a recent report by ESCWA, as much as 80% of diseases in the ESCWA region are directly or indirectly attributable to water (11). It is generally agreed that most of the serious health problems in the region are directly related to water. Inadequate disposal of domestic wastewater, especially in urban areas, is a cause of diarrhoea and gastrointestinal diseases, through direct ingestion of polluted water or through consumption of vegetables grown with contaminated water. The health effects resulting from other pollution sources, such as agro-chemicals used in agriculture or industrial toxic wastes, are not well-quantified in the region, but may pose an even greater long-term effect on public health.

Polluted water has more general effects on the environment and economy. It has resulted in:

(a) Damage to recreational areas, reducing quality of life for citizens and often discouraging tourism and reducing available foreign exchange;

(b) Altering the ecological environment of lakes and oceans, reducing the amount and variety of fish from lakes and oceans and having other long-term effects on the aquatic and wildlife environment;

(c) Reducing the amount of water available for agricultural use, and reducing production and/or quality of products.

Worldwide, as urban populations are rapidly growing, international aid agencies are focusing more and more of their efforts on attempts to combat urban environmental issues, particularly in pre-urban slum areas. The ESCWA region, with 60% of its population living in urban areas, is no exception. Urban water systems are generally highly inefficient, losing up to 50% - 60% of water available supply as "unaccounted for water" either through illegal tapping or leakage. Industrial areas are most often located in and around urban areas. Agricultural areas are also sometimes close to urban areas, owing to available wastewater and water supply and accessible markets. For example, in the Syrian Arab Republic, the largest agricultural producing area is in the Damascus Basin and it receives, without treatment, all the domestic waste for the city of Damascus. Marine environments are also threatened. In Egypt, the brackish lakes north of the Nile Delta receive 16 bcm of agricultural drainage, sewage and industrial wastes yearly (7).

Pollution of water can be from a variety of sources and can be defined as the changes in the natural physical, chemical, and biological characteristics of a receiving water caused by the discharge of any material into that water that detracts from beneficial use (8). Water quality in the ESCWA region is also affected by high salinity, especially in the areas or countries such as Gaza and Jordan which are already exceeding the annual recharge of their renewable supplies. However, salinity, which results from overabstraction of water, is another major cause of the deterioration in groundwater quality.

The three main users of water—the domestic, agricultural and industrial sectors—are also the main pollutants of water, in addition to solid waste pollution from industry and domestic users. An investigation of water pollution is best approached through analysis of water use and its effect on water quality.

Egypt, and the Syrian coast, factories discharge wastes directly into the sea. In the Gulf, oil industry effluent is in some cases discharged into the sea.

6. *Pollution from solid waste*

Solid wastes from industry can also cause water pollution through groundwater seepage and/or flow from rivers into the sea. Solid waste management in the ESCWA region is generally in unsanitary landfills; this causes seepage into groundwater, surface water and from there to the sea.

7. *Impact of sea water intrusion and brine disposal*

Water quality deterioration resulting from sea water intrusion and brine disposal adversely affected vast cultivated areas in the ESCWA region (Oman and Gaza). Brine disposal from sea/brackish water diminishes agricultural land progressively and imposes economic losses.

8. *Institutions and legislation*

The issue of institutions and legislation was addressed by a recent ESCWA Expert Group Meeting on water legislation in relation to water resources management (9). Basically, the laws and regulations which were effective half a century ago are no longer effective in managing the volumes and quality of effluent being produced by urban populations, industries and agriculture. Strict, enforceable legislation is needed, backed up by a clear institutional authority for each country and/or water basin in order to manage both supply and waste aspects of water use.

9. *Objectives and scope of work*

Recent studies (8, 38) have pointed out the need for an integrated look at water quantity and quality, and have addressed the issue of water scarcity and conservation. A recent ESCWA report on assessment of water quality (11) focuses on these issues and presents a regional overview of water quality in the region. In follow-up of that report, in order to better understand the specific issues, the present study investigates the status of water pollution in three urban areas; Damascus, Jeddah and Gaza. The study covers the Damascus Basin, the city of Jeddah, and the entire Gaza Strip, which encompasses information on the rural areas surrounding the cities. An integrated approach is taken, looking at the specific water uses and how they in turn contribute to water pollution.

The present study was carried out in fulfillment of the ESCWA programme activity for 1996-1997 entitled "Water pollution in selected urban areas, case-studies of Damascus, Jeddah and Gaza". The study devotes special attention to the disposal of brine resulting from the desalination processes and the effects thereof. The study is composed of two parts. Part one contains an analysis of the water resources situation and sources of pollution in the three cities under consideration namely: Damascus, Jeddah and Gaza. Part two addresses the impact of brine disposal on the water supply and urban areas. The recommendations mainly focus on measures and policies that could be adopted by the concerned officials in the countries and areas under consideration.

PART ONE

WATER POLLUTION CASE-STUDY (Damascus, Gaza and Jeddah)*

* References for part one, including the introduction, are cited in the text by numbers enclosed in parentheses; the corresponding complete references are provided in the references to part one.

I. CASE-STUDY: DAMASCUS CITY

A. GENERAL DESCRIPTION

The proportion of the Syrian population living in urban areas was estimated at 3.2 million in 1975; the population had increased to 5.3 million by 1985 and is expected to reach round 10.5 million by the year 2000, which represents a threefold increase during the last quarter of this century. Continued migration from rural areas to urban areas aggravates the urbanization problem, which can be attributed the lack of opportunities in the agricultural sector and the greater availability of social services and opportunities for economic betterment in urban areas. The environmental consequences of this rapid urbanization have been felt in many cities in the Syrian Arab Republic, where the quality of public services has been affected; this has been coupled with a deterioration in environmental quality in terms of water and other natural resources.

The water supply for urban settlements is drawn from surface water and groundwater in an almost even proportion. The capital Damascus is supplied with spring water which is chlorinated before distribution. The distribution system is old and in need of rehabilitation in some areas, which results in significant water losses in the network. About half a million refugees living in assigned city districts are served by a separate network supplied from deepaquifers. The average per capita consumption in urban areas was estimated to be from 150 to 170 litres per day (l/d). The Government planned to extend water supply coverage to more than 95% of the urban population and to 90% of the entire population by 1995. There are occasional discussions on revising the tariff system, but government policy has been against any attempt to raise water prices, especially when low-income areas will be affected. However, general policy is to discourage wastage in the high-income areas. At present in the Syrian Arab Republic, about 70% of the urban population is served by a sewerage system. During 1985, the pre-construction phase for sewerage and sewage treatment plants for six major cities was scheduled to be completed, in addition to the commissioning of the sewage treatment works of Damascus.

Industrial activities are concentrated in major urban settlements. Refineries are located in Homs and Baniyas while textiles, fertilizers, cement, food-processing and mechanical industries are located in Damascus, Homs and Aleppo. Adjacent residential areas are increasingly suffering from adverse environmental effects emanating from industrial liquid, solid and air pollution. A proposed law for abatement of water pollution has not yet been ratified. The Ministry of Environment is placing emphasis on the abatement of industrial pollution through the adoption of emission standards, the incorporation of environmental impact assessments in licences and permits and the provision of support for control of pollution at source. The Ministry of Health monitors water quality and environmental pollution, and the State Planning Commission coordinates all environmental programmes of the different government agencies within the framework of plans. The constraints on enhancing the urban environment may be attributed to the following:

(a) Lack of sufficient financial resources;

(b) Rapid rate of urbanization and migration to urban areas from rural areas;

(c) Increasing pollution of water resources, surface and groundwater, owing to uncontrolled discharge of pollutants;

(d) Lack of adequate data and information for the development of long-term plans.

Damascus has been selected for inclusion in this study as an example of the effects of urbanization in the Syrian Arab Republic, and the connection between hydrological/hydrogeological conditions and water pollution problems.

However, the major environmental issues attributed to water quality problems that seem to affect the sustainability of water resources development include a rapid decline of groundwater levels and deterioration of groundwater quality, waterlogging and salinization of agricultural lands, and pollution of surface and groundwater due to the discharge of drainage water, as well as untreated effluent from municipalities and manufacturing industries. The increase in population, particularly in urban centres, and the proliferation of industries in major cities and elsewhere have contributed to the increased exploitation of the limited surface water resources, the volume of which depends on the sharing of river waters with riparian countries.

TABLE 3. WATER RESOURCES IN THE SYRIAN ARAB REPUBLIC

Basin	Area (sq.km)	Precipitation		Annual water resources (mcm)		
		mm	mcm	Surface	GW	Total
Barada & Awaj	8560	268	2297	833	850	1683
Orontes	21643	403	8722	1110	1607	2717
Coast	5100	1294	6603	1557	778	2335
Dehleh and Khabour	21129	402	8493	788	1600	2388
Euphrates	40083	182	7295	175	25	200
Yarmouk	6724	287	1930	180	265	447
Steppe	70786	138	9800	163	182	354
Aleppo	11155	304	2396	303	346	649

Source: (2)

A major plan to assess and control the effect of pollution of water sources in the Syrian Arab Republic is under way. The Ministry of State for Environmental Affairs has completed a draft law on environmental affairs, which when approved, will give the Ministry executive powers to deal with pollution control and environmental safety.

C. OVERVIEW OF WATER POLLUTION ISSUES IN THE SYRIAN ARAB REPUBLIC

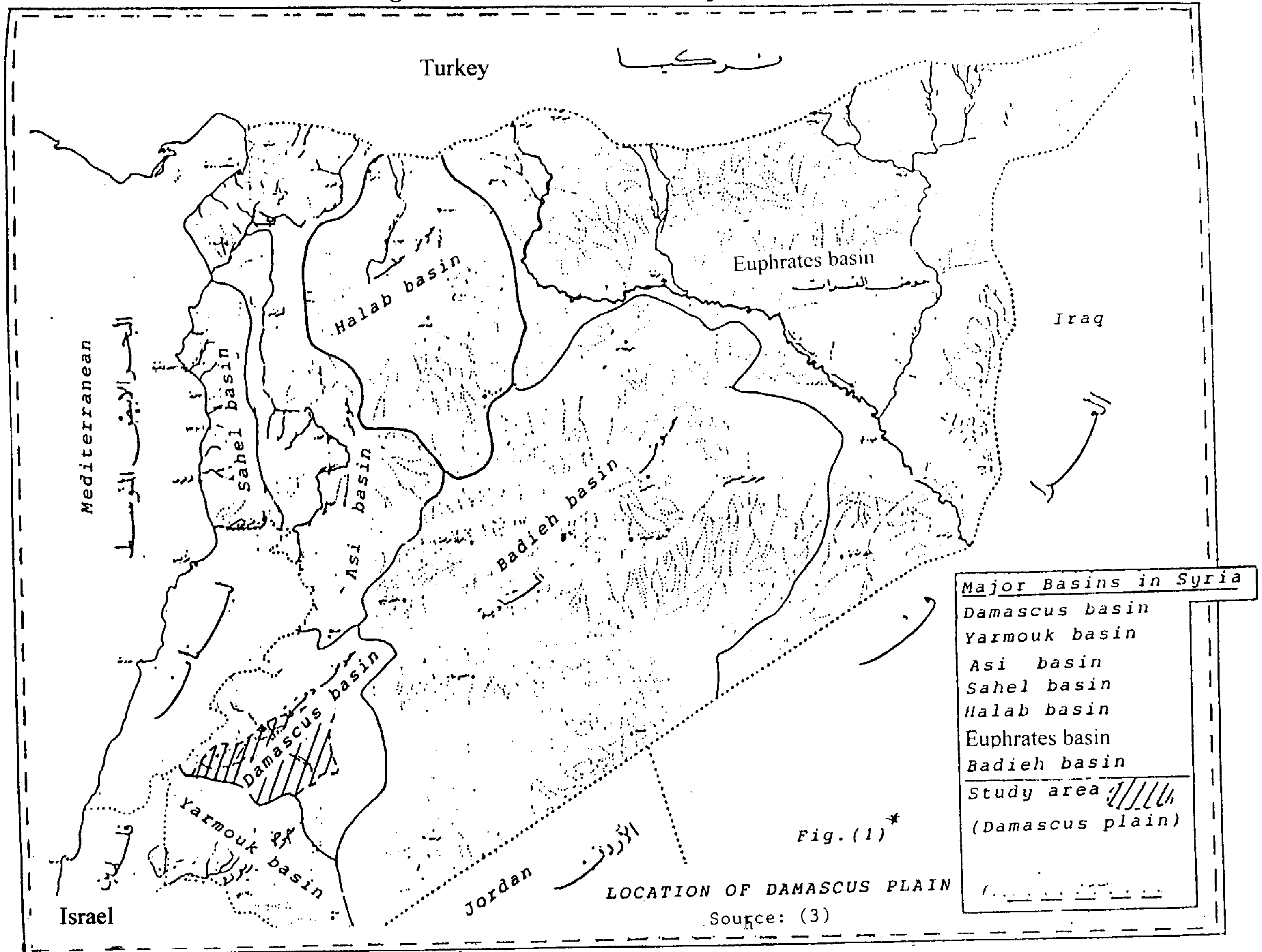
Up to 85% of the Syrian Arab Republic water resources are usable only in the sparsely populated northern regions; the more urbanized and industrialized southern and western regions are facing problems with both water quantity and quality. Overall demand for water has increased with increased urbanization, industrialization and agricultural production (12, 9). Industrial production rose from 35.1 billion to 41 billion Syrian pounds (LS), and the total area of irrigated land reached 1.2 million hectares, about double the 1970 areas. The overall population growth is about 3.8% but growth in urban areas is higher, up to 5% in Damascus (13), where water demand for domestic and industrial uses exceeds local water supplies.

There is no metering of Syrian industrial and agricultural use of water, and therefore data on allocation of water use and demand are approximate. Recent ESCWA calculations based on country papers and international sources estimate allocation as follows for 1990:

Domestic	8.4%
Agriculture	89.7%
Industrial	1.9%

The increased water use has had both direct and indirect effects on water quality. Except for the medium-sized town of Salamiyah, all urban and rural domestic, industrial and agricultural effluent is discharged untreated onto open land or rivers, or, in coastal areas, directly into the sea. In addition, solid

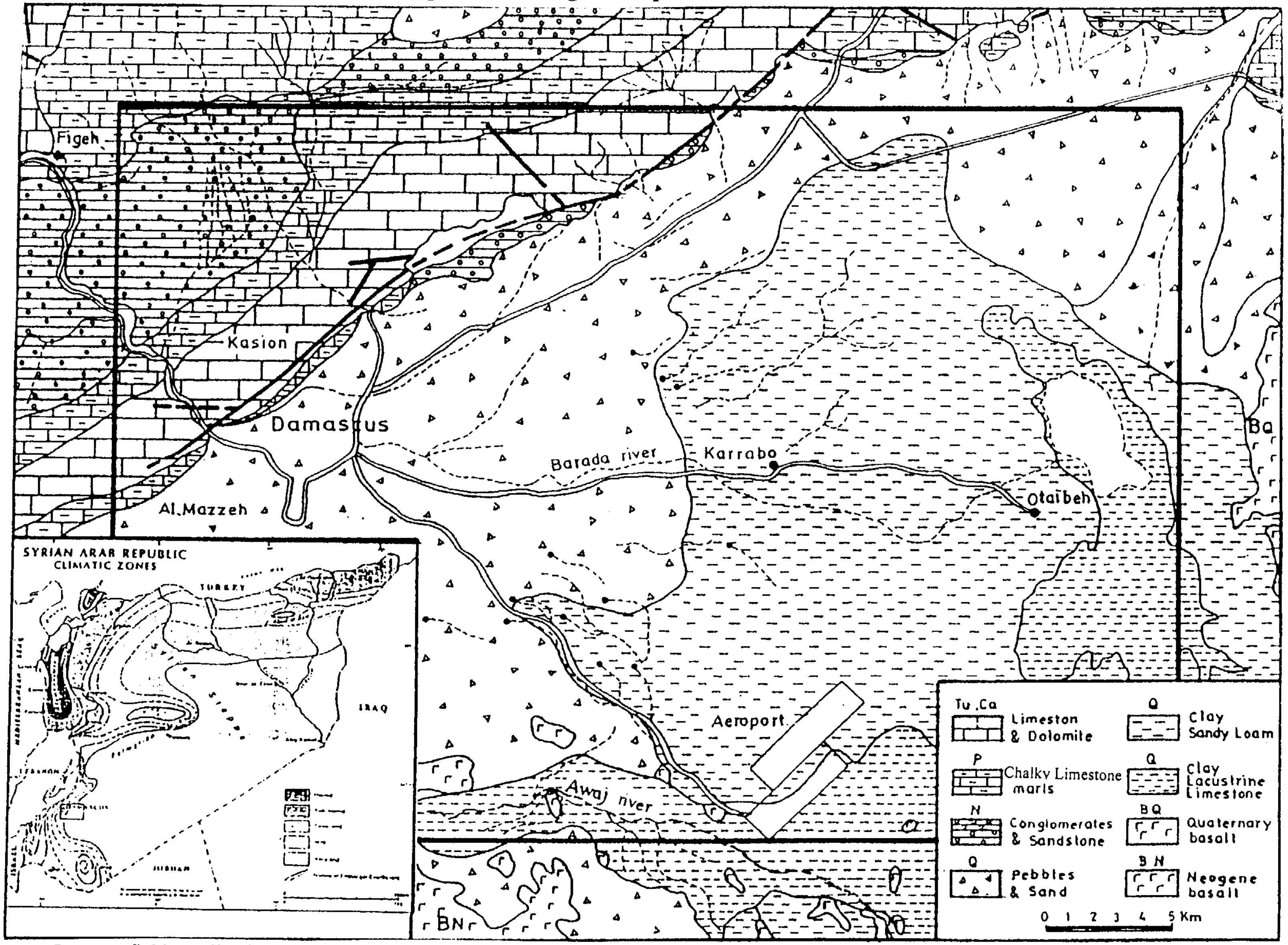
Figure 1. Location of Damascus plain



Source: N. Rofail and S. Al-Koudmani, Evaluation of the groundwater observation network of Damascus plain, UNDP/WMO/ACSAD Regional Training Workshop on Design of Groundwater Networks, Riyadh, 23-27 February 1986.

The boundaries and names shown on this map do not imply official endorsement by the United Nations.

Figure 2. Geological map of Damascus basin



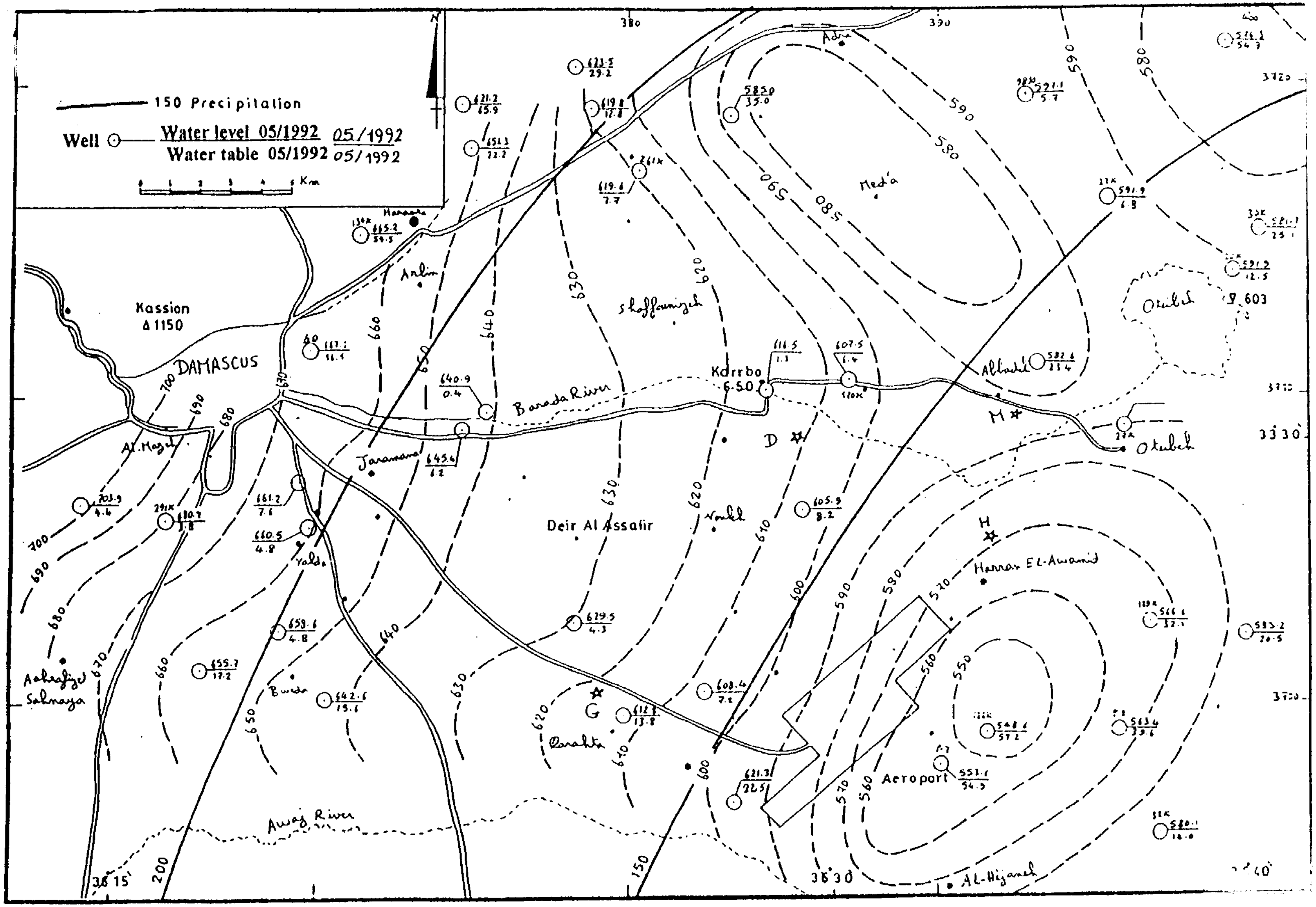
Source: Isotope field applications for groundwater studies in the Middle East, Proceedings of the final coordination meeting of a regional technical cooperation project held in Ankara, Turkey, 21-25 November 1994.

The boundaries and names shown on this map do not imply official endorsement by the United Nations.

There is a group of contact springs in the central part of the Damascus plain; some flow in a north-north direction and some in a south-west direction. They are found between the proluvial deposits and limestone-marly (figure 3). The total discharge from these springs exceeds 3 cm/sec, but there has been continuous depletion and most of these springs are dry, especially in summer. The increased demand and the depletion of the Feigha source in summer, as well as sewage water drainage, cause progressive deterioration of water quality. Environmental isotopes have been used to ensure proper management and development of these aquifer systems in the Damascus plain and to assess the recharge area, replenishment rates, groundwater flows and the interconnection of the Feigha main spring and Feigha side spring (the source of water supply for Damascus city). One of the results of the study indicates that the maximum groundwater reservoir of the Feigha main spring reaches a value of about 3.9 bcm.

A change in water quality and chemical composition is taking place in the Damascus plain. Salinity increases towards the east. It reaches over 5 g/L near El-Oteibe and El-Haijaneh lakes. The influence of the Barada River is obvious in the western part of the plain, where salinity does not exceed 1 g/L. The chemical composition of the groundwater changes from hydrocarbon in the west to sulphate-chloride in the east. Studies on micro-organisms in the Damascus plain show a very high degree of contamination. This is due to the fact that the Barada and Al-Awaj rivers receive discharges of sewage and industrial waste.

Figure 4. Piezometric map of Damascus basin



Source: N. Rofail and S. Al-Koudmani, Evaluation of the groundwater observation network of Damascus plain, UNDP/WMO/ACSAD Regional Training Workshop on Design of Groundwater Networks, Riyadh, 23-27 February 1986.

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groundwater and, indirectly, into the municipal water supply. As part of the ongoing Damascus Wastewater Treatment Project, the sewerage network has already been upgraded, and a new trunk main to a new sewage treatment plant 22.5 km from Damascus has nearly been completed.

In the rural areas around Damascus, and parts of the city and Palestinian refugee camps, households are served by seepage pits, which are emptied periodically by tankers which discharge the domestic waste in open areas, often near groundwater sources or on the riverbank. The pits themselves are also sources of pollution, through leakage to the groundwater table (15).

Agricultural activities are of great concern to Syrian officials, owing to the high levels of fertilizers and pesticides used in farming in the Al-Ghouta Plain. There has been a net increase in sales of most fertilizers in the past five years, some of which have even doubled. Sales of imported pesticides almost doubled from 1990 to 1992, then halved again by 1994 (13).

Industrial wastewater is discharged directly into the Barada River, with no treatment. Although much smaller in amounts than domestic wastewater, industrial wastewater is potentially much more harmful and requires very careful treatment and disposal. Industrial waste can increase BOD, elevated salinity, nitrogen compounds, heavy metals, high alkalinity or acidity and organic chemicals such as solvents, oil, grease and other hydrocarbons. In recent years, more and more chemicals are available from overseas, and are imported without specific controls or training as to their proper use and disposal. More modern, technologically advanced equipment is also used, often without proper training in operation and maintenance. No detailed studies of industrial pollution in the Damascus area have been carried out.

3. *Water quality and public health*

Health problems in Damascus and the Ghouta basin have been detected and linked to drinking water from boreholes with high coliform counts and from consumption of raw vegetables irrigated by untreated wastewater. There are reports of parasitic diseases, which would be a result of irrigation of untreated vegetables with domestic sewage (14). The long-term effects of industrial pollution have not been studied, nor are any studies available with information on pollution from industrial or agricultural uses of water.

Surface water quality studies have been carried out by the Water Pollution Control Department of the Ministry of Irrigation on 36 sampling points on the Barada River since 1979. Although the written report was not available, its general conclusions were reviewed by government officials. Although the source of water (Barada Spring) is clean, water quality is inadequate for drinking just below this site. As the river reaches Damascus, water quality is still adequate for irrigation, but by the time the river has received the full domestic wastewater supply from Damascus as it flows out of the city, quality is inadequate for irrigation purposes. Government officials attribute the pollution to the discharge of domestic and industrial wastewater directly into the river.

Various studies have been conducted on groundwater in the Al-Ghouta Plain to determine the extent of the aquifer and monitor salinity and water levels (14, 24). Lowering of the groundwater table was noted in several locations, causing concern not only about water pollution, but also of overabstraction, with very high rates of pumping noted in some areas. Water quality monitoring of boreholes indicates that salinity increases towards the eastern part of the plain, reaching over 5 g/L. The Water Pollution Control Department of the Ministry of Irrigation has recently commenced regular water quality surveillance of 21 groundwater sources in the Damascus basin but results are not yet available. The Department is testing for bacterial quality, and levels of copper, iron and chrome. Although the Department has an atomic absorption unit for testing for additional metals, the technical staff need training in operating the unit before a full programme of testing can commence (13).

needed in order to plan specific interventions. ACSAD has initiated some activities on this subject, but the results have not been published.

There is little local expertise in industrial wastewater treatment, and no enforceable legislation to require industries to treat their effluent (13). Specific data are also lacking in order to make informed, cost-effective decisions on industrial treatment. A feasibility study on management of tannery waste is scheduled to be issued by ESCWA in 1997, and will provide recommendations for combining waste from several tanneries for treatment and recycling. In order to alleviate industrial pollution of water, the Government plans to set up an industrial estate at Adhra, where the sewage treatment works will be located. It is not clear, however, whether established industries will be required to move there or, if they do, whether pre-treatment of their effluent will be required before discharge in the new treatment works. If the effluent is allowed into the sewage treatment works, it will cause considerable damage to the treatment process. A continuing programme of regional training activities on industrial pollution by the Inter-Islamic Water Resources Development Network has provided some assistance to local experts.

C. Legislation and institutional management

The Syrian Arab Republic has a long history of specific rules and regulations concerning water resources management, for domestic, irrigation and industrial purposes. Current water pollution control legislation, however (Law No. 2145, 1974), has no enforcement provisions. For example, there are regulations covering industrial effluent, but the Water Pollution Control Department only has the power to "advise" and "ask" industries to comply with these regulations. Every factory is required by law to name an engineer responsible for water and pollution control, but, in practice, wastewater treatment is expensive and there must be incentives, economic or regulatory, to encourage industry to comply with effluent standards.

The Syrian Arab Republic has very specific and detailed rules relating to water use for irrigation– drilling boreholes, pump sizes, rates of pumping, and fines as means of enforcement. Enforcement comes under the domain of the Ministry of Irrigation. However, in practice, these rules are difficult to enforce. The Ministry of Irrigation, in collaboration with other Government agencies, has drafted detailed legislation controlling water use and water pollution, including specific regulations on effluent standards for industry. The draft legislation has been submitted for approval, but it is still pending.

Water pollution control in the Damascus basin comes under the realm of various ministries and government departments, as outlined below. The various functions of the water sector are outlined below together with the responsible ministries.

1. *Water resources development and management*

The Ministry of Irrigation, according to Ministry officials, has overall responsibility for managing water resources, and collaborates with other Ministries in planning the development and implementation of water-related projects. Dam construction comes under the realm of this Ministry.

2. *Domestic water supply and wastewater management*

The Ministry of Housing and Utilities is responsible for constructing and managing water supply and sewerage distribution and treatment networks. The semi-autonomous Damascus Water Supply and Sewerage Authority is attached to this Ministry. It also includes the Feigha Administration, which is responsible specifically for providing water from Feigha Spring.

III. CASE-STUDY OF THE GAZA STRIP

A. WATER RESOURCES

The Gaza Strip is situated along the Mediterranean Sea between Israel and Egypt. The length of the Strip, from Rafah in the south to Beit Hanun in the north, measures 45 km, and width ranges from 507 km in the north to a maximum of 12 km in the south. The total area is 365 km^2. The Gaza Strip has a Mediterranean climate, with hot, dry summers and cool, wet winters. The mean annual rainfall in Gaza town is approximately 260 mm, with the range in the Gaza Strip from 200-400 mm, depending on location.

The population density for the entire area is approximately 2,165 inhabitants per sq km, but is much higher in refugee camps, ranging from 28,905 to 100,230 inhabitants per sq km. The 1991 population was estimated at 830,000, with the current birth rate, one of the highest in the world, at approximately 6%.

The main institutional authority in Gaza is the Palestinian Authority, which manages all aspects of life in Gaza with varying levels of additional control by the Israeli Government, the former occupying authority. (Exceptions to this are the Israeli settlements and military zones, over which the Palestinian Authority has no jurisdiction.) All access to Gaza by land or by sea is strictly controlled by Israel, to the extent that even Palestinian Authority officials from the West Bank are required to obtain permits for day visits. Since a strict border closure in February 1996, access both in and out of Gaza for people and goods has been severely limited. Therefore, Gaza is extremely isolated, both politically and economically.

In the past, around 70% of the GDP of Gaza came from daily wage labour in Israel, but now, owing to strict border closures, unemployment is currently over 70%. Within Gaza, employment is mainly in agriculture, services and a few small industries.

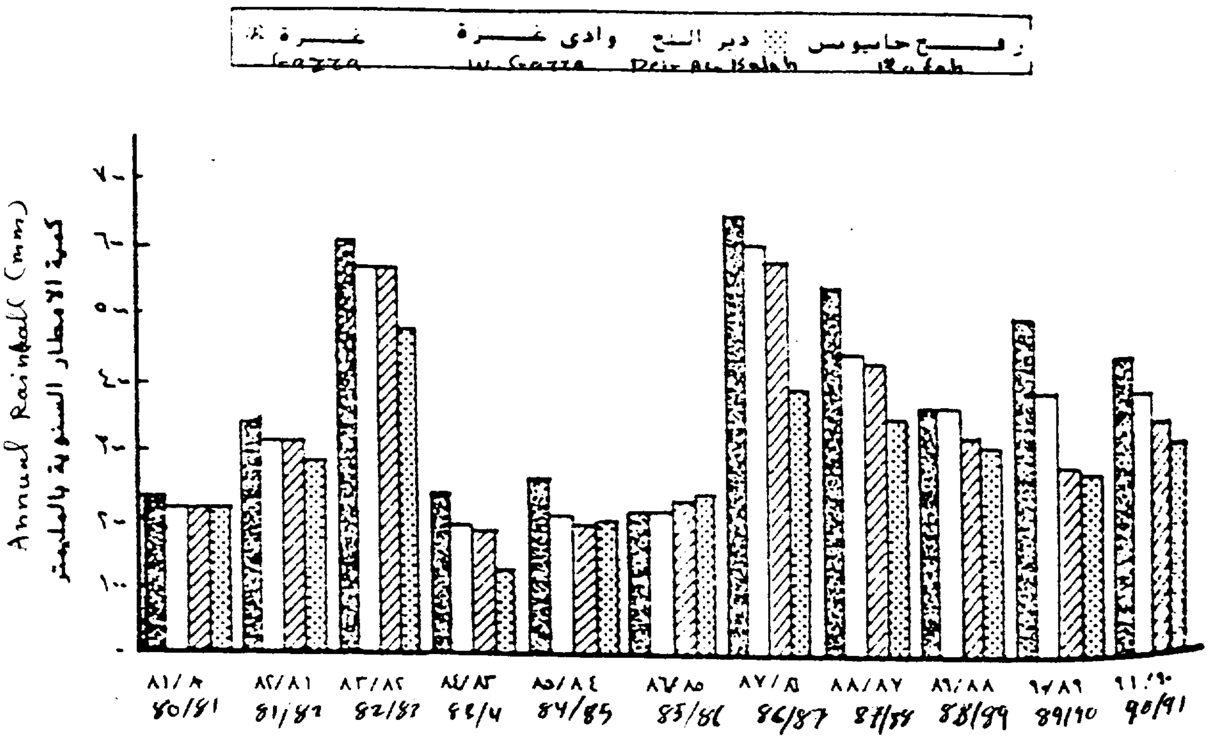
During the years of occupation, the provision of basic services in Gaza was extremely limited. Environmental health services provided by municipal councils depended solely on the availability of funding from international aid organizations. In the refugee camps, the United Nations Relief and Works Agency for Palestine Refugees in the Near East (UNRWA) provided assistance in the form of schools, water, sewerage and drainage projects, and community health services. No overall strategy existed for environmental planning, and inputs by outside agencies were scattered and limited. Pollution of groundwater, sea water and of open land resulted from inadequate water supply and sewerage systems and solid waste dumping. In addition, the groundwater sources in Gaza were and still are being rapidly depleted.

Since the takeover of the Palestinian Authority in Gaza in 1994, a form of government has been established and attempts have been made to address the many neglected economic and social problems plaguing Gaza. Many bilateral, multilateral and private aid agencies have promised to provide assistance in improving environmental health conditions. Sometimes in collaboration with agencies of the Palestinian Authority, sometimes independently, a myriad of reports, analyses and recommendations has been compiled, all in some form addressing the issue of water pollution.

B. OVERVIEW OF AVAILABLE RESOURCES

Surface water in Gaza is limited to the 3,500 sq km river basin of Wadi Gaza, which discharges into the Mediterranean only on the 10 days/year in which there is any significant flow. Its flow is limited owing to intensive cultivation in the area, and an upstream dam in Israel. Gaza therefore depends on its own groundwater resources for water supply, as well as groundwater imported from Israel.

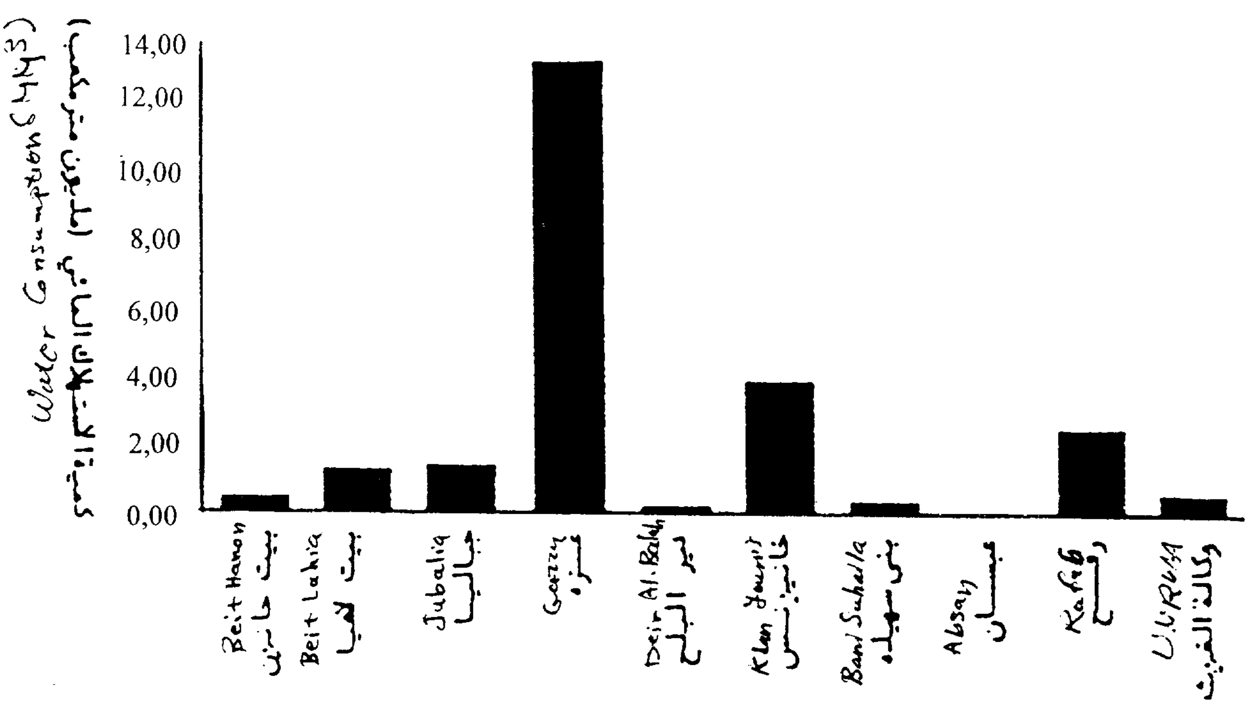
Figure 6. Mean annual rainfall in Rafah, Deir Al-Balah and Gaza City



Source: Y. Abu Maylek, Water requirements for Gaza Strip, *Water Science Magazine* (14th issue), October 1993 (in Arabic).

The boundaries and names shown on this map do not imply official endorsement or acceptance by the United Nations.

Figure 8. Drinking water consumption in Gaza Strip (mcm)



Source: Y. Abu Maylek, Water requirements for Gaza Strip, *Water Science Magazine* (14th issue), October 1993 (in Arabic).

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(c) Tanker water obtained from private wells;
(d) Rainfall collection (very few households).

Wells for domestic supplies are managed by municipalities and are often located close to households. Municipalities tend to dig deeper wells in order to obtain more water, even though the less brackish water more appropriate for household use is generally available closer to the surface. The distribution system is old and in need of repair. Between the leakage and illegal connections, unaccounted-for-water estimates are as high as 45%-50%. The effectiveness of chlorination efforts is also hindered by the lack of a reliable supply of chlorine (owing to Israeli restrictions on imports) and lack of training in operation and maintenance of chlorination equipment.

There have been no household-based studies on water use. However, based on total water distributed and accounting for losses, estimates of use range from 50 lpcd to 75-110 lpcd (19). The Environmental Planning Directorate currently uses an average rate of 90 lpcd for its calculations. This is still below acceptable health levels, and it would be desirable to raise this amount given available water supplies. Water demand projections, assuming an increase in population and per capita use, estimate a doubling of domestic water use from 30.74 lpcd (1990) to 64.39 lpcd in the year 2010 (figure 8).

D. AGRICULTURAL WATER SUPPLY

Approximately 110,000 dunums are under irrigated cultivation in Gaza, mainly citrus crops (50%) and other vegetables and fruits (50%). Generally, the more water-efficient form of drip irrigation is practised and there is limited experimentation with rainwater collection on greenhouses. In the past, strict metering of boreholes made it possible for Israel to estimate actual water use with some accuracy. The Coordinator of Government Operations in 1986 reported water abstraction of 110 mcm/year (19). Currently, owing to the higher number of boreholes with broken (intentionally and unintentionally) meters and unregistered boreholes, more current estimates are based on land area and cropping patterns.

A limited number of farmers also use raw wastewater for irrigation. It appears that they are aware of the health risks, but they prefer this source as it is inexpensive and they would not be willing or able to pay for cleaner water.

Estimates by the Environmental Planning Directorate in 1996 predicated that there would be a decline in water demand for irrigation owing to a shift from citrus to other horticultural crops which have a better export market, require less water and, in some cases, are less sensitive to high levels of salinity. Other sources point to various factors which could result in either a decline or an increase in demand for irrigation water.

Increased demand could result from:

(a) Low pumping costs, amount to US$ 0.10/cm in 1990, less than the subsidized cost of US$ 0.14 in Israel;

(b) Current lack of restrictions on borehole abstraction;

(c) Increased land area irrigated (Bruins estimates an additional 80,000 -100,000 dunums are available for irrigation).

Decreased demand could result from:

IV. POLLUTION CONTROL MEASURES IN GAZA

A. BASIC CONSIDERATIONS

1. *Water quality and public health*

Although the public health risks of water pollution are widely known, it is always difficult to prove the effects of specific pollutants on the health of the population. In Gaza, where there are irregular health records and no comprehensive epidemiological studies, this task is especially difficult. Water quality testing is carried out on a more or less regular basis by the Ministries of Health and Agriculture, municipalities and some non-governmental organizations (NGOs) active in water and the environment. In addition, specific testing has been carried out by some consultants.

The Government has no adequate testing lab, and relies on the Islamic University for results.

Testing is not possible for the full range of possible pollutants, especially specific chemicals resulting from agricultural, industrial or solid waste. Bruins (19) tested the water quality procedures by submitting samples to local laboratories for testing and also sending samples overseas. In testing for nitrates, it was found that, although in both cases the results were above the acceptable levels, nitrate levels reported by the Gaza laboratory were double those reported from the overseas laboratory.

In 1994, a team of consultants reviewed records from 1988 to 1993 on fluoride, chloride and nitrate content in 50 wells and showed that the quality of water supply wells was poor to fair with salt, nitrate and fluoride content rather high and often above acceptable limits. In 1992, the salinity level was above the acceptable limit of 250 mg Cl/L in 65% of the wells. The nitrate content was above the limit of 45 mg/l in 86% of the wells. There was a large variation in results from one well to another. Data on agricultural wells indicated that the chloride content, generally over the WHO limits, increased from year to year in several locations.

The Palestinian Authority has unofficially adopted WHO guidelines for water quality, and compliance by municipalities with Ministry of Health requirements is satisfactory but not complete. When bacteriological contamination is reported within the distribution system, remedial action is discussed by the Ministry of Health and the respective municipal council. Chlorination is the most common corrective measure.

No specific data are available on the effect of water pollution on the marine environment, but the potential health hazards are through direct skin and eye contact and consumption of marine animals exposed to effluent. There are 1,500 licensed fishermen in Gaza and their livelihood and the health of consumers could well be damaged through sea water pollution.

2. *Salinity*

High salinity is distasteful, but does not have any known detrimental health effects. Saline water, however, negatively affects soil content and is one of the factors discouraging farmers from growing citrus crops, which are particularly sensitive to salinity.

High nitrate levels can result from pollution from agro-chemicals, high sewage content and/or solid waste leachate. The Environmental Profile (1993) maps nitrate levels for 1990, indicating only approximately 25% of groundwater resources with less than 200 mg/l nitrates; the WHO acceptable level is 50 mg/l. More specific studies indicate nitrate levels of 30-60 mg/l outside of refugee camps; this is assumed to be a result of agricultural level. Higher levels of 150 mg/l of nitrate found in well water of

Groundwater is polluted by:

(a) Saline water intrusion from overabstraction;

(b) Domestic wastewater dumped indiscriminately by vacuum tankers;

(c) Domestic wastewater from household cesspits;

(d) Domestic wastewater from leaking sewers;

(e) Municipal wastewater from overflowing drains owing to lack of conveyance capacity and/or blockage by solid waste;

(f) Municipal wastewater from non-operational sewage treatment plants;

(g) Contamination in distribution and storage from leaking wastewater conveyance systems and tankers;

(h) Solid waste leachate from municipal dumps and indiscriminate dumping;

(i) Industrial wastewater.

The salinization and pollution of the groundwater pose a major environmental threat to the people and land of Gaza, with the following results:

(a) Domestic consumption of water contaminated by domestic, agricultural, industrial and solid waste;

(b) Domestic consumption of crops irrigated with contaminated water;

(c) Lack of safe beaches for recreational and tourist use;

(d) Deterioration of the quality of soils for agricultural use;

(e) Damage to the ecologically fragile dune areas.

The various pollution sources are summarized below. They include overexploitation, domestic and municipal wastewater, agricultural wastewater, industrial waste dumping and solid waste.

With respect to overexploitation, the rate of abstraction of freshwater sources is from 2 to 5 times greater than the rate of recharge. A UNICEF Environmental Profile carried out in 1995 estimated that at current rates of use, good quality water with minimum saline content in the aquifer would be depleted in 15-20 years and repletion would require decades without any abstraction. Salinization can be caused by sea water intrusion and, in the case of deep boreholes, of saline water coming up from deep within the aquifer. There are no data on the extent of either cause, but both of them result from overabstraction of groundwater.

For domestic and municipal wastewater most households have, within the household, a sanitary system of disposal of domestic wastewater, with limited health hazards. However, the conveyance, storage and treatment (or lack thereof) of domestic wastewater pose numerous hazards. Approximately half of the households in Gaza dispose of their wastewater by conventional sewerage systems; the other half have household cesspits. Most sewerage systems are in need of upgrading and are inadequate in quality (causing

The UNRWA camps are generally well-covered by waste collection systems, but service levels vary in the rest of Gaza. Municipal dumps are not managed as sanitary landfills; in some cases, a small depression is dug before dumping and reuse of the effluent. The full extent of contamination of groundwater is not known. In Rafah, for example, a major dump site is located only 250 m from a municipal borehole. However, since the borehole obtains its water from a confined aquifer, it is possible that no contamination reaches it from the dump. No water quality tests have been carried out on this borehole. A successful, ongoing education programme for solid waste management in Gaza city has been used as a model for other parts of the Gaza Strip. This includes Solid Waste Management Councils made up of citizens and municipal officials who work together to solve solid waste management problems.

C. POLLUTION CONTROL MEASURES

Government officials are well aware of the acute need for water pollution control measures in Gaza. In a 1996 report by the Environmental Planning Department on water pollution control, it was noted that the water situation in Gaza was critical, with the process of deterioration uncontrolled. The report also noted that there is no national strategy yet to cope with it, and if this does not change, then the remaining freshwater will disappear in the next several decades without an alternative being available.

Many studies have been carried out on different aspects of the environment in Gaza, all of which refer to water pollution as the most pressing ecological issue. Many activities to date have mainly involved information collection and feasibility studies, with little actual progress on the ground. Almost all the European countries, as well as Canada, the United States, Japan, and all of the various United Nations agencies are providing inputs in Gaza. There are several active local NGOs, as well as a few international ones such as Save the Children. A comprehensive listing of current activities was not available, but an outline is given below of the various measures being taken or planned to alleviate water pollution problems.

One of the most important requirements to ensure pollution control is to have reliable data with which to analyse pollution causes and effects. In this manner, Government can develop priorities for action based on the most pressing needs. Several agencies, both governmental and non-governmental, are working on developing reasonable statistics for decision-making, but there is to date no comprehensive monitoring and surveillance system in place which will provide planners with the data needed to take decisions about water pollution control.

As for development of human resources, the European Community is funding management training for municipalities and town councils to assist them in planning and implementation. Projects funded by outside agencies often bring with them experienced staff, and provide in-country or overseas training. The Islamic University in Gaza is setting up an Environmental Studies Department with one of its priorities being water pollution control. Although it may take a few years to be fully operational, this should provide an excellent local source of training in pollution control measures.

Recommendations have been made to provide specific, emergency protection for “fresh” groundwater resources, but these require political and economic decisions, as these resources are generally located in Israeli settlements or on private land over which landowners have water rights. Based on the above, the following proposals have been made, taking into consideration different situations.

1. *Overabstraction*

There are only two solutions to overabstraction: reduce wastage and increase overall water supply. Increasing the overall water available can be carried out through three general methods:

campaign on non-toxic alternatives and more economic farm management. PARC is working on sustainable agricultural programmes, which would also include reduced use of agro-chemicals; 25 consultants from various scientific, engineering and social science backgrounds have recently formed the Environmental Protection and Research Institute, with one of its goals to establish an extension programme in Gaza and construct an environmental chemistry and toxicology laboratory.

4. *Industrial waste dumping and wastewater and solid waste*

An Environmental Impact Assessment will be carried out before the final development of the new Industrial Estate in Gaza. The extent of activities controlling current industrial waste and wastewater dumping is not known.

In the past, the focus in solid waste programmes has been on collection systems. UNRWA is working on developing its disposal systems and established through funding a master plan on collection, disposal and treatment of solid waste is being established through funding from Germany.

D. LEGISLATION AND INSTITUTIONS

The Palestinian Authority is effectively a new Government without full control of the area which it is supposed to govern. Given its limited funds, lack of skilled manpower, and difficulties with managing day-to-day political and economic crises, the task of setting up institutions and legislation to control environmental issues has not always been a top priority. Past laws (a combination of Israeli military and civil decrees and civil Egyptian laws) are no longer followed and, indeed, any type of government enforcement is associated with "Authority", which in the past was the Israeli military government.

In the first year of the takeover of the Palestinian Authority in Gaza, an Emergency Resource Protection Plan was developed, but it has not yet been approved by the President. The Environmental Planning Directorate is working on draft legislation to control pollution, but with the Protection Plan not approved, there is no immediate prospect of approval of additional legislation. Despite the current and dangerous levels of over abstraction of water, there are no effective disincentives or incentives to limit the rate the rate of water consumption.

There is no legal framework that provides the opportunities to prescribe and enforce proper land use practices, to control the use of agro-chemicals, or to control indiscriminate dumping of solid waste or wastewater. According to a 1995 Environment Profile, every sector and even every individual seem free to expand or intensity their interests without limitations and without concern for other user groups or land use functions.

As in many countries, responsibility for water supply and pollution control rests with various government and other agencies with overlapping responsibilities. In Gaza, the situation is particularly confusing, as the various government agencies are generally operating only on draft terms of reference for their activities, with no final approval of their roles and responsibilities yet given by the President. In addition, the Government of Israel severely limits access to Gaza for Palestinian Authority officials, consultants and other experts who are residents of the West Bank. This restricts Gaza from receiving assistance from many professionals and discourages easy communication and management of government agencies.

Although there are many locally qualified professionals, the sheer magnitude of problems facing the Palestinian Authority and the specific technical knowledge needed in some fields have required the assistance of outside experts. Numerous local and international NGOs, multilateral and bilateral aid agencies, and local universities are active in various aspects of pollution-related activities. Millions of

Several Palestinian Authority agencies (the Environmental Planning Directorate, the Palestine Water Authority, the Palestine Environmental Protection Authority) are responsible for domestic wastewater. Even the Ministry of Agriculture has a role to play. The debate is partly over whether domestic wastewater is a "water resource" or a "pollutant". The final decision rests with the President.

UNRWA plays a large role in Gaza in environmental sanitation and health education, extending even beyond the refugee camps.

Agricultural water supply and wastewater

The Ministry of Agriculture is responsible for agriculture-related activities, but it is not clear what its authority over water abstraction is. In the past, the Ministry had a Directorate General of Water, but reportedly its authority will be transferred to the Palestine Water Authority.

F. POLLUTION CONTROL

The task facing administrators and planners in Gaza in addressing environmental problems is formidable. At the same time, the Palestinian Authority has been beset with political problems which have often overshadowed all other activities, no matter how crucial they may be to the Palestinian people. There are many government and private agencies addressing various aspects of water pollution control. The major problems facing them are similar to those in many Middle Eastern countries, but are more drastic in most cases owing to the current extent of water pollution and continuing pollution. The pollution problems are a result of the following:

(a) Lack of clear institutional structures;

(b) Lack of legislation and enforcement mechanisms to control water use or wastewater;

(c) Lack of comprehensive land use planning and/or integrated water resources management;

(d) Lack of a comprehensive water resources monitoring programme, providing sufficient data to make policy decisions, especially as regards industrial pollution and pollution of sea water;

(e) Lack of expertise in specific fields, particularly in industrial pollution and wastewater treatment and reuse;

(f) Lack of awareness at all levels of pollution-related issues and possible solutions;

(g) Lack of funding.

Major infrastructural improvements and political decisions are needed to make any significant difference in water use and pollution in Gaza. This is beyond the scope of ESCWA activities, and ESCWA should, in Gaza, concentrate on specific areas in which it can provide assistance through regional or local activities.

1. *Industrial water use and pollution*

Industry in Gaza is limited, but industrial pollution may none the less be significant. A comprehensive study on industrial water use, effluent and potential pollution and health impact would fill a specific gap in current information available on Gaza and provide a guide for future industrial development in the area.

V. CASE-STUDY OF JEDDAH

A. PHYSICAL SETTING

Jeddah, "the Bride of the Red Sea," is a coastal city of great age. Its name is said to be drived from the Arabic translation (Jeddah) of the name "grandmother," reflecting the belief that Eve (the mother of mankind) was buried somewhere in the old city. This name was perhaps given to the old city because of its great age.

Jeddah's geographical location, on the eastern coast of the Red Sea, offers a number of advantages which have, over the years, enhanced its importance as a major coastal port. The importance of Jeddah and its prosperity are due to its strategic location, adjoining both the city of Mecca and Medina. The two holy cities have been centres for religious and trading activities for more than 14 centuries. The emergence of Islam and the widespread influence of the Islamic religion have resulted in increasing trade combined with an enormous amount of pilgrimage traffic through the city of Jeddah. In recent decades, the city has grown rapidly and has developed as a result of the expansion of the oil industry. This growth has been associated with commercial and industrial expansion, which has generated significant development, as can be seen in the expanded general port area and fish market, as well as the oil and gas refineries, the desalination and power plants, and the wastewater treatment works.

The vast pattern of development has greatly influenced the conditions for management of the city and its environment today. However, the complexity and dynamics in growing urban areas such as the city of Jeddah have always challenged decision makers. This challenge has been complicated further in the last two decades with the increased awareness of environmental concerns. With the rapid urbanization over the last 50 years throughout the world, and particularly in the developing world, many of the environmental effects of today were not foreseen at the time that major urbanization was taking place. In any developing city (such as Jeddah), there are many environmental management issues such as solid and hazardous waste disposal, air quality deterioration, and, for coastal cities, coastal and marine resource management. However, water management is still the most significant issue and the most complex, especially in the Middle East. Therefore, water pollution in Jeddah is described in the present report within the context of water management issues.

1. *Location and physical setting*

Jeddah is located on the eastern coast of the Red Sea (figure 10). The city is bounded by the Al Sarawat Mountains on the eastern side, and the Sharm of Obhor on the northern side, as well as the Alkhomrah from the southern side. Jeddah is considered to be a focal transportation node adjoining both of the two holy cities of Mecca, 75 kilometres to the east, and Medina, 427 kilometres to the north. Jeddah is situated around 950 kilometres south of Alaqbah, and 820 kilometres north of Jizan. The maritime distance across the Red Sea to the Suez is 1,138 kilometres; it is 304 kilometres to Port Sudan.

The general area where Jeddah is located is free from any significant topographic relief. Only gentle swells and coral rock outcrops show where erosion or man-made cuts left traces on the topographic surface. A process of alluvial deposition combined with upward movement of the land relative to the sea gave rise to the Tihama coastal plain. Its average width in the vicinity of Jeddah is about 12 kilometres. In the pluvial periods associated with the Pleistocene glaciation in higher latitudes, deep river valleys were cut to a Red Sea level sensibly lower than the present one, narrow bights of deep water penetrating nearly perpendicularly to the coast for some distance and affording many excellent harbours. In this way the various sharms (watercourses) of the Red Sea coast were formed. Sharm Obhor, which is located 40 kilometres north of Jeddah, owes its origin to this process.

TABLE 7. MONTHLY RAINFALL AVERAGE (mm PER MONTH) IN JEDDAH, 1962-1995

Year	Monthly average	Increasing order	Returning period (yr)
1962	75	6	6
1963	25	20	1.71
1964	18	22	1.56
1965	46	13	2.76
1966	34	15	2.4
1967	33	17	2.11
1968	93	4	9
1969	125	1	36
1970	55	11	3.27
1971	99	3	12
1972	83	5	7.2
1973	10	26	1.33
1974	15	24	1.44
1975	16	23	1.4
1976	20	21	1.9
1977	56	10	3.6
1978	67	8	4.5
1979	102	2	18
1980	33	17	2.11
1981	11	25	1.39
1982	1	33	1.06
1983	3	31	1.13
1984	5	29	1.2
1985	40	14	2.57
1986	0	34	1.03
1987	5	30	1.16
1988	28	19	1.9
1989	51	12	3
1990	2	32	1.09
1991	8	28	1.24
1992	68	7	5.14
1993	58	9	4
1994	9	27	1.29
1995	32	18	2

Source: Meteorology and Environmental Protection Administration, Saudi Arabia.

Figure 11. Average monthly rainfall in Jeddah, 1962-1995

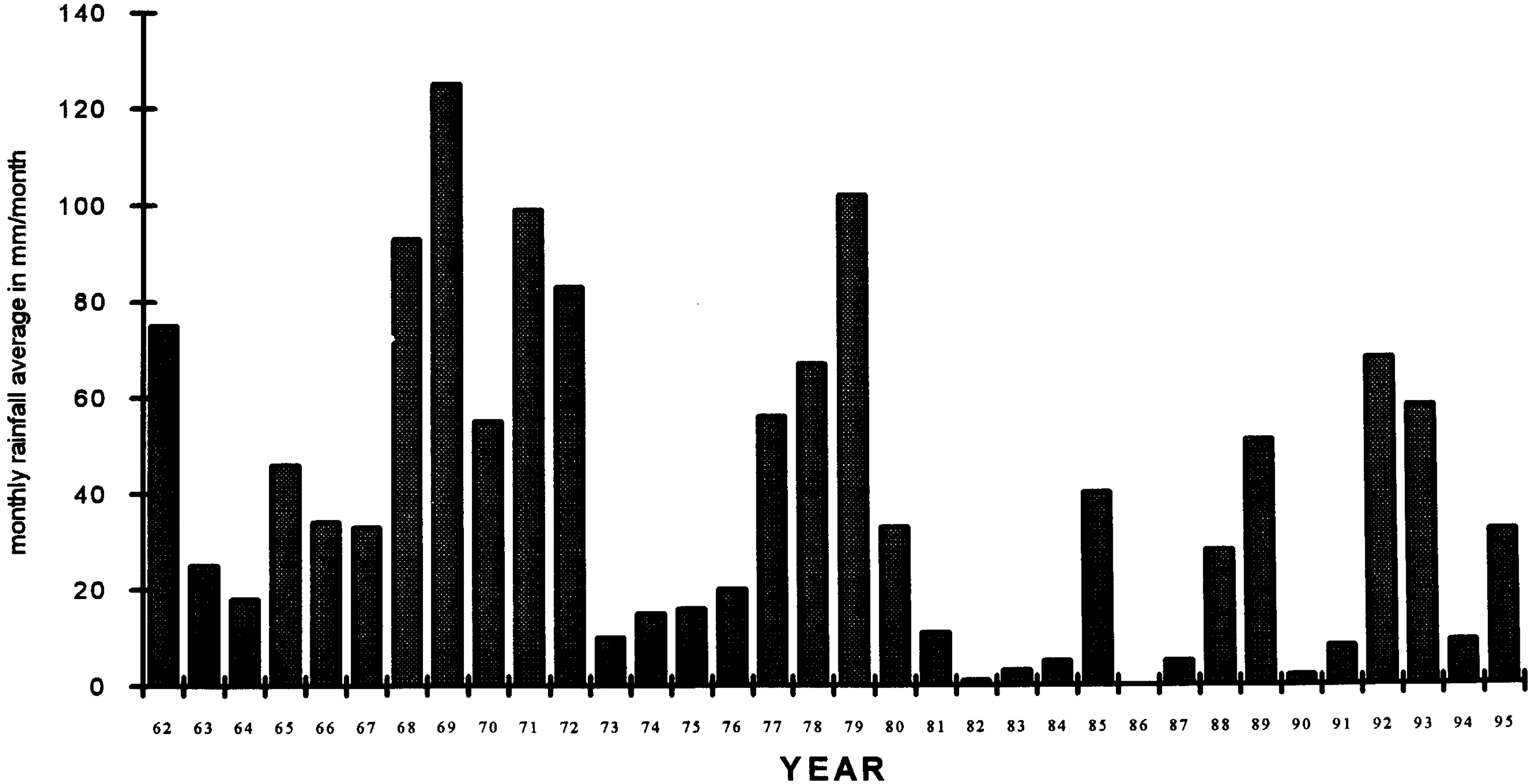


TABLE 8. JEDDAH'S URBANIZATION GROWTH IN SQUARE KILOMETRES

Period interval	Gross area (km^2)	Five-year increments
1946	1.90	----
1946 - 1951	3.15	1.25
1951 - 1956	10.65	7.50
1956 - 1961	14.60	3.95[a/]
1961 - 1966	21.15	6.55
1966 - 1971	32.50	11.35
1971 - 1976	66.50	34.00
1976 - 1981	114.15	47.65
1981 - 1986	225.55	111.40
1986 - 1991	700.00	474.45
1991 - 1996	1200.00	500.00

Source: Municipality of Jeddah.

a/ Growth decreased owing to the closing of the Suez Canal and inflation

TABLE 9. JEDDAH'S POPULATION ON A DISTRICT BASIS, 1971-1978

District	Year 1971	Year 1978	Increase/decrease	% Inc/dec
1.Karantina	21810(5.7)	24909(2.9)	+3099	+14.2
2.Hulail	15980(4.2)	37904(4.4)	+21924	+137.2
3.lthalebah(Khuzam)	32840(8.6)	91862(10.7)	+59022	+179.7
4.Alnuzlah Y(khzam)	26130(6.9)	19872(2.3)	-6258	-23.9
5.Bukharia	22840(6.0)	28129(3.3)	+5289	+23.2
6.Al Hindawiyah (Al Balad)	5350(1.4)	36892(4.3)	+31542	+589.6
7. Alshtea	13740(3.6)	23529(2.7)	+9789	+74.2
8. Alsabeel (Al Balad)	22540(5.9)	39215(4.5)	+16675	74.0
9. Harat Bara	11180(2.9)	9407(1.1)	-1773	-15.8
10. Alsuhafah	17300(4.6)	25599(3.0)	+8299	+48.0
11. Alnuzha s.(Khuzam)	20470(5.4)	30751(3.6)	+10281	+50.4
12. Kilo 6-10	20530(5.4)	43769(5.1)	+23239	+113.2
13. Kilo 1-5	15270(4.0)	129352(15.)	+114082	+747.1
14. Yamen(asham)	57700(15.2)	41952(4.9)	-15748	-27.3
15.Albugdadyah(albald)	18410(4.8)	68448(4.8)	+50038	+271.8
16.Alkandarah(albald)	20550(5.4)	36616(4.2)	+16066	+78.2
17.Sharfia	10000(2.6)	44574(5.2)	+34574	+345.7
18. Bani Malek	6190(1.6)	28313(3.3)	+22123	+357.2
19. Al Rawais	18330(4.8)	59409(6.9)	+41079	+224.1
20. Mushrefah	3840(1.0)	28818(3.3)	+24978	+650.5
21. Mushaeefah	0(0)	13042(1.5)	+13042	
Total	381000(100)	862362(100)	+481362	+126.3

Source: M.J. Abdulrazzak and A.V. Sorman, Domestic Water Conservation Potential: New Resources for the Major Cities of the Western Region, Final Report 1416, King Abdulaziz University, Faculty of Meteorology, Environment and Arid Land Agriculture, Department of Hydrology and Water Resources Management, 1996.

Note: Items in parentheses ( ) indicate percentage of total areas.

Figure 12. Jeddah: historical urban expansion

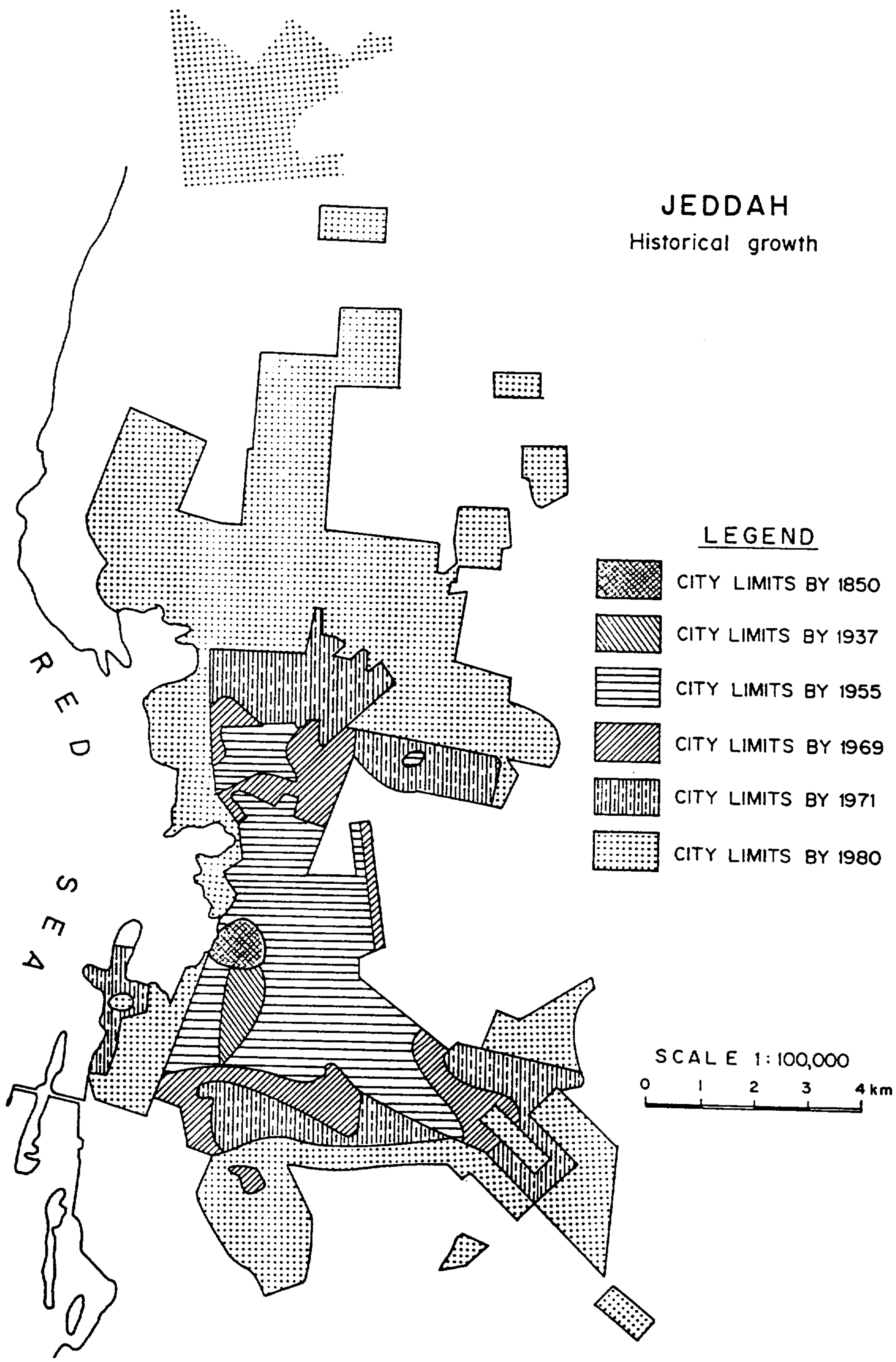
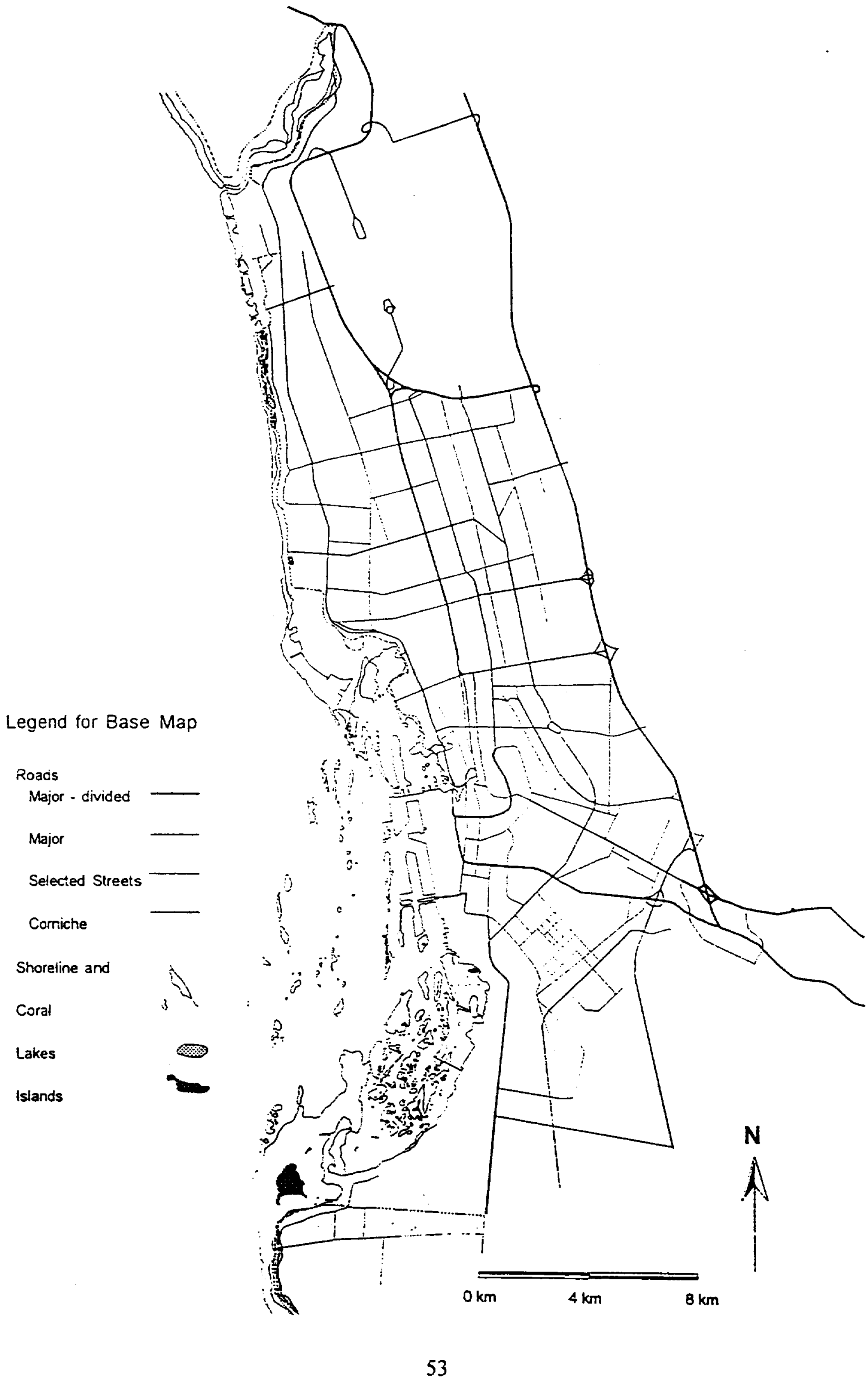


Figure 14. Base map for Jeddah



Water from Wadi Fatima was transported to the city through parallel asbestos-cement main pipes 375 mm in diameter. An 800-mm reinforced concrete main runs to reservoirs situated 14 km away on the Mecca road east of the city. The combined capacity of the reservoirs was estimated at 63,580 cu m (elevation 71 masl); chlorine was added to the water before it reached the reservoirs. Water from the reservoirs was conveyed to the city through 12 main pipelines covering a distance of 12 kilometres. The main system consisted of two asbestos-cement lines, one of which was 375 mm in diameter and the other 500 mm. Water from the reservoirs was pumped to the east into a higher distribution network after being chlorinated. The main lines flow into smaller pipes. Water from Wadi Khulays was transmitted through an asbestos-cement pipeline 800 mm in diameter to a conditioning plant with eight reservoirs near Medina road north of the city (see figure 15). The capacity of all the water storage facilities for the city was estimated at 244,600 cu m. The distribution network within the city consisted of the north, main and eastern zones. A total of 72,104 house connections was completed in 1982 for these three zones (21).

Currently, the water distribution network covers 80% of the city, with diameter of the pipes ranging from 25 mm to 1,000 mm. The length of the water distribution network of Jeddah is around 3,885 km. There are 3,600 fire hydrants connected to this network (Municipality of Jeddah). Existing reservoirs have a combined capacity of 560,000 cu m. In addition, there are small reservoirs located in Qawazah, Prince Fawaz District, with storage capacities of 10,000 cu m and 5,000 cu m respectively. The network covers a total of 122,139 building connections (21).

2. *Desalinated water*

As noted above, the first small-capacity boiler was installed in 1909 and was producing around 300 cu m per day by the 1940s (23). When the economic situation improved in the Kingdom, the development of a reliable water supply became Jeddah's highest priority. A reliable water supply is crucial for Jeddah because of the low amount of rainfall in the area where the city is located, and its unpredictability, as well as the insufficient supply of water from groundwater, which does not meet the rapidly growing demands. Naturally, sea water desalinization became the primary option to meet the city's increasing demand for water. The first major desalinization plant came on line in 1970 with daily production of 18,300 cu m (24). Since that time, Jeddah has become dependent on sea water desalinization for its survival. The city also relies on groundwater resources as shown in table 11 and illustrated in figure 16.

Water produced by the desalinization plants is pumped to conditioning plants in the northern parts of the city (on Macarona Street) where it is blended with water drawn from groundwater sources (Wadi Fatima and Wadi Khulays) to introduce the desired mineral content. Owing to extensive mining of groundwater from the shallow alluvial aquifers, the city has become dependent on the water from a number of desalinization plants.

In Jeddah, there are several desalinization plants serving the general population and specific facilities. The Jeddah Sea Water Conversion Corporation (SWCC-Jeddah desalinization plant) supplies the largest volume of water. In 1995, the daily production of desalinization plants in Jeddah was 427,500 cu m. The volumes of groundwater supplied to Jeddah from Wadi Fatima and Wadi Khulays were 7,155 cu m and 15,366 cu m per day respectively. The total volume of water produced and the actual locations of all other plants in Jeddah are not known, but the Port Authority and Airport combined produce approximately 11 million gallons per day (23).

estimated at 29.48 mcm. The daily per capita usage was estimated at 213 litres. Estimates of past and future per capita water consumption, based on the data from different surveys, are shown in table 12.

Figure 15. Sketch of network supply from Wadi Fatima and Wadi Khulays

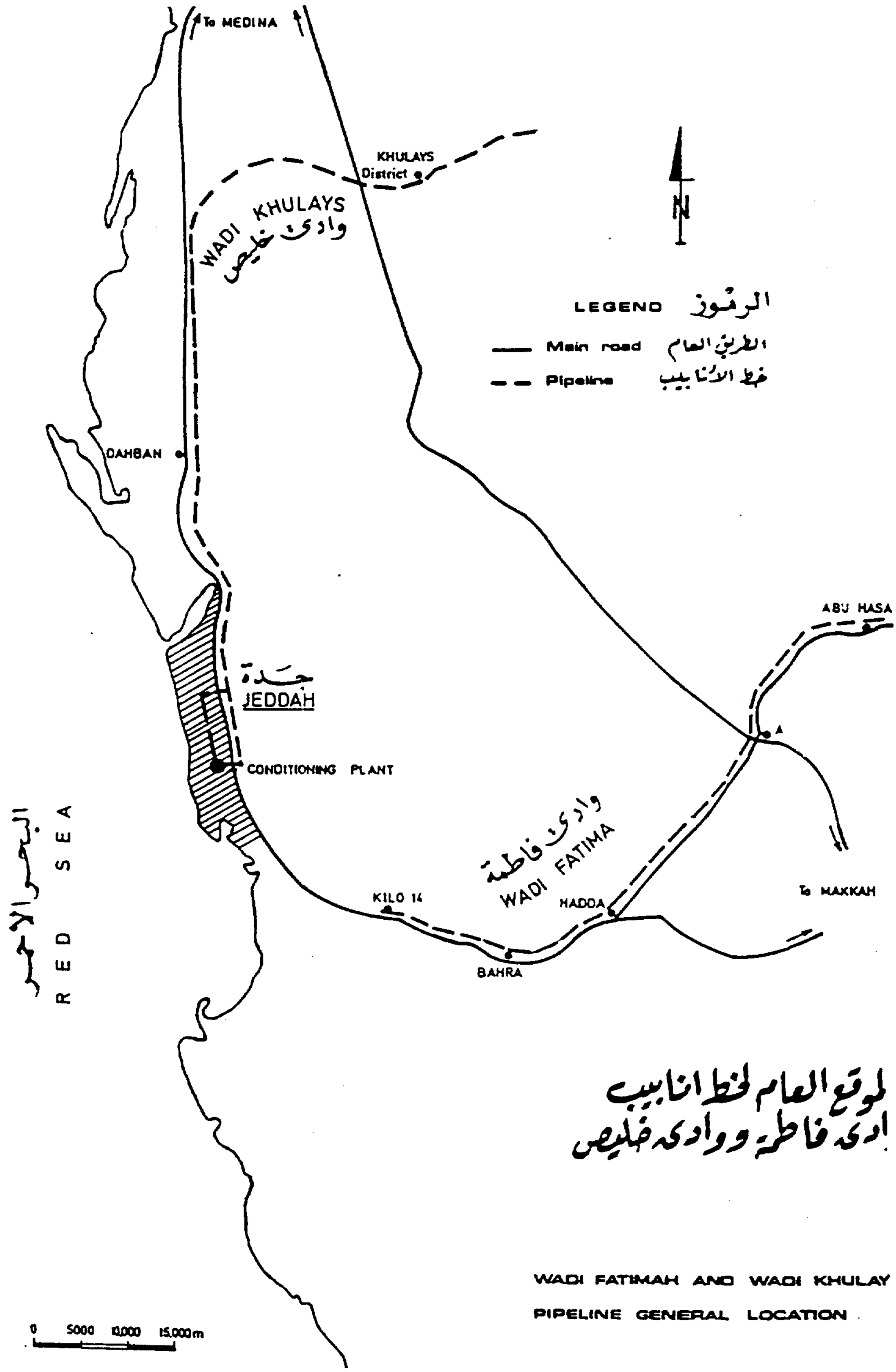


Figure 17. Jeddah: existing water supply network

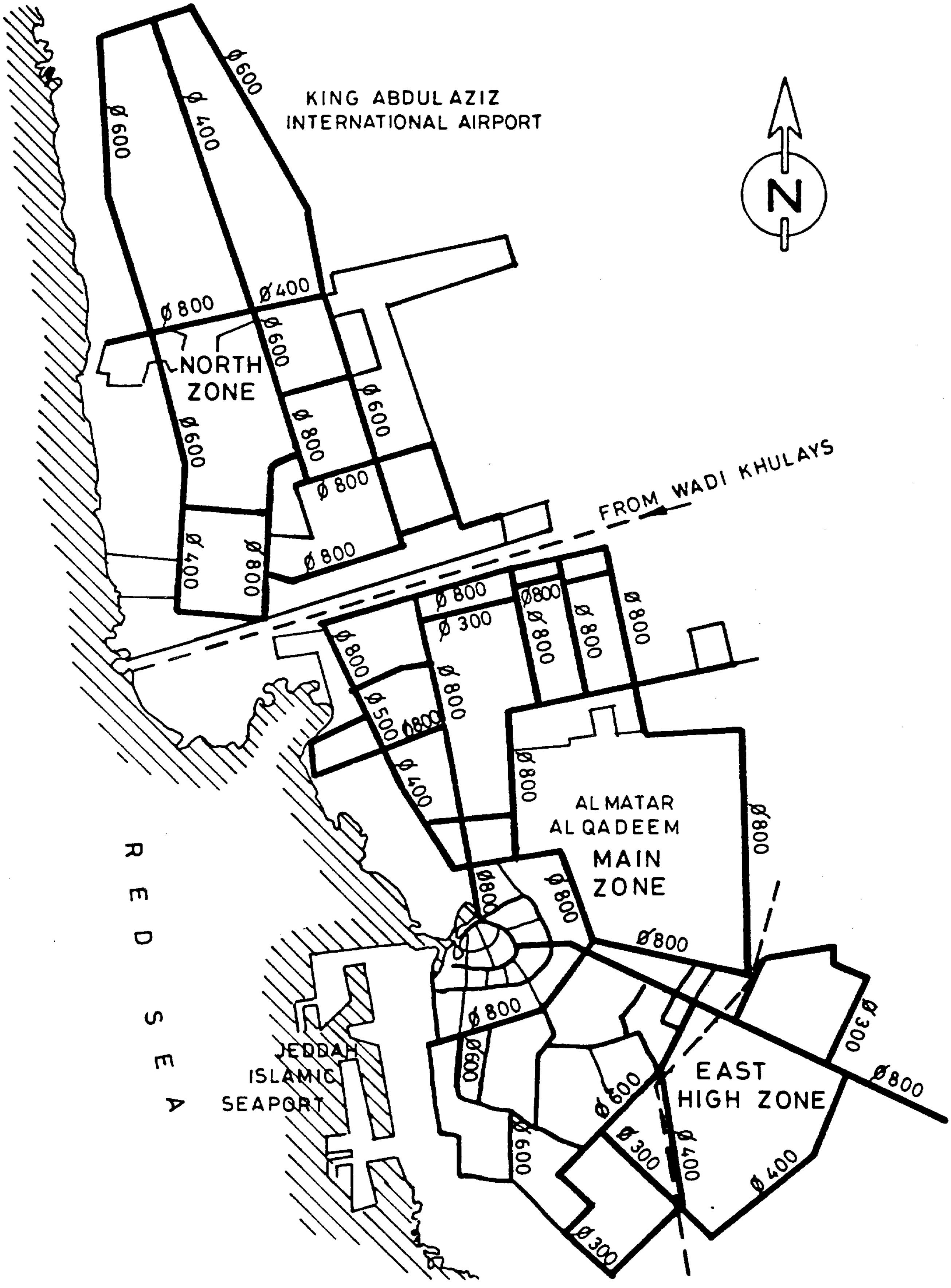


TABLE 13. PAST AND FORECASTED LOCAL WATER DEMAND

	1990					2000				
	Level of services (%)	Population or area	Rate Cu.m	Water demand (Cu.m/d)	Demand LPD	Level of services (%)	Population or area	Rate Cu.m	Water Cu.m/d	Demand LPD
Domestic	90	1 600 000	0.210	302 400	189 (44)	100	2 250 000	0.230	517 500	230(52)
Non-domestic										
- Central function	90	21 760	25/ha	62 100	39 (10)	100	3 010	25	75 250	33(7)
- Manufacturing	45	1 200	45/ha	24 300	41 (41)	50	2 980	45	67 050	68(15)
- Warehouse	4	2.620	7/ha	8 250	-	50	2 700	7	9 450	54(11)
- Parks	0		-	-	47 (47)	0	2 420	-	-	-
Subtotal				397 050					669 250	
Waste and losses		17.5%		84 220			15%		118 100	68(15)
Total				481 270					787 350	68(15)
Balance supplied from the non-drinking water supply system				131 090					232 350	

Source: "Jeddah, extension of water distribution system, study and design, interim report", by SOGREAH Consulting Engineers (Grenoble, Francel and SEVRECA Consulting Engineers (Paris), April 1992 (Jeddah, Saudi Arabia Ministry of Agriculture and Water).

Note: LPD = litres of water per day.

VI. WATER POLLUTION CONTROL IN JEDDAH

A. SOURCE OF POLLUTION

1. *Arbaeen lagoon*

Al-Arbaeen Lake, as the citizens of Jeddah call it, is a semi-closed body of water located in the heart of the Old Town of Jeddah, adjacent to an urbanized area, and connected to the Red Sea at its western end (figure 19). The total area of the lagoon was calculated at approximately 290,000 square metres. The depth of the lagoon ranges between about 3 metres in the northern part to 1.4 metres in the southern part (Nasmet- Aljanonb lagoon) with an estimated volume of water about 700,000 cu m.

The lagoon has been receiving large amounts of sewage for a long period of time and has not been able to assimilate it naturally. This lagoon has become more closed off, particularly since the bridges were constructed. Thus there is a slow exchange of water with the sea. This situation results in low oxygen content in the water. Marine life in the lagoon cannot survive, and the high potential of the area as an attractive and valuable resource is negated. In addition, the lack of oxygen does not allow any of the material entering the lagoon—sewage or other decaying matter—to biodegrade naturally. The result has been a built up thick layer of sludge, from two to three metres. This volume of material has further reduced the exchange of water and oxygen in the lagoon. The result of all these circumstances is the continuous generation of odours, and the creation of an unhealthy environment. Furthermore, the lagoon is considered a major health hazard for the public at large; if left unattended this problem will certainly cause an epidemic of communicable diseases.

After several investigations and studies, many solutions have been proposed. The resolution of the odour problem closely related to the resolution of other water management issues, in particular the sewage treatment system for the entire city. Actions are being taken to eliminate dumping of sewage into the lagoon but these measures are expensive and should probably be carried out in the broader and longer-term context of sewage treatment for the entire city.

An interdepartmental committee (formed by order of the Governor of Mecca) set three goals with a view to solving the odour problem. They are: eliminating the raw sewage from the present sewage and storm water discharges; improving the water quality of the lagoon; and resolving the problems of the sludge. In the long run, it may also be desirable to increase the natural exchange of water in the lagoon to improve the total value of this unique area in the centre of the city.

2. *Sewage treatment*

The Water and Sewage Authority in the Mecca region reported that although there are six municipal wastewater treatment plants operating under its jurisdiction (namely Iskan, Bani Malek, El-Gamah, Plant A, Plant C and El-Kumrah, only 65% of the population and 35%-40% of the area is covered by a sewerage network. The first three sewage treatment plants are small, with capacities of 3,000, 9,000 and 11,000 cu m per day respectively; they are operating, by and large, within their capacities. The other three large-capacity plants operate over their design capacity, at 32,000, 40,000, and 40,000 cu m per day respectively: these plants actually run at a capacity of 60,000, 70,000 and 75,000 cu m per day respectively. The authority has also reported that the actual per capita generation of sewage is 55 cu m per person per year, which provided

The existing capacity for sewage treatment, collection and disposal cannot handle the present volumes. Facilities are working over their design capacity (25) (figure 20). Raw sewage is being dumped into areas such as the Arbaeen lagoon, resulting in the unpleasant odours in the central business district. It is also suspected that other sources of sewage caused by back-ups and flooding are ending up in the storm water drainage system and eventually in the harbour area. This too may be a secondary source of odours along the Corniche and downtown areas.

New developments in the northern part of the city are not being hooked up with the sewage system so that removal by pumping to trucks and on-site disposal or treatment are the only alternatives. Figure 21 shows the areas serviced by sewage systems. In some cases, for residences and commercial developments along the coast, there is direct dumping into the sea. There are continuous occurrences of flooding owing to backups of the sewage system onto the streets. This sewage in turn gets into the other storm drainage system and eventually the sea. Odour problems then develop in many areas of the city.

There are around 450 industries currently in operation in Jeddah. Few of these industries use dry process discharging only sanitary waste. The rest use wet process discharging effluents into the industrial city sewerage system which ultimately go to the industrial wastewater treatment plant operated by the Ministry of Industry. This plant is not designed to handle the types of waste generated by the many and varied industries currently located in Jeddah's industrial city. This means there is only partial treatment of the industrial city's wastewater. The outlet of this treatment plant is connected to the El-Khumrah sewage treatment plant, which is an aerobic biological treatment plant and does not have the facilities to treat the non-biodegradable organic compounds present in the industrial waste. Nevertheless, part of the plant's effluent is used for irrigating greenery on the city streets and the rest is discharged into the Red Sea.

There have been several recommendations made to resolve the issue in the Arbaeen lagoon area. Stopping the discharge of sewage into the lagoon is the first step. For the remainder of the coast, the owners of sources of discharges are being identified and notifications to stop are being sent (table 15). It is still unknown at this time as to what are the best ways to resolve the entire issue regarding odour and water quality in the lagoon area. Plans are being developed and implemented to deal with the sewage capacity problems in the city; however, these require time to implement and significant financial expenditure.

3. *Sewage removal and treatment sites*

A significant area (approximately 66% of Jeddah) does not have access to central sewage treatment facilities. Much of the area is located in the northern part of Jeddah. Sewage is collected in on-site tanks or vaults, picked up by truck and disposed of at collection lakes to the north-east of Jeddah or simply in the desert. On site disposal uses deep wells, treatment through septic and leaching systems, and through direct disposal into the sea. In addition, there is a group of industries in the industrial city which, however critical from a water pollution point of view, has not been allowed by the industrial city administration to be connected to the industrial wastewater treatment plant because of the high pollution load of their effluents. These industries dispose of their liquid discharges on land in an unknown desert area through private contractors.

The problems that have arisen include: the capacity of the present lake/disposal site has been reached and a new location is being developed near Briman; there is a rise in the level of the groundwater in

Figure 21. Sewage treatment plants and serviced areas

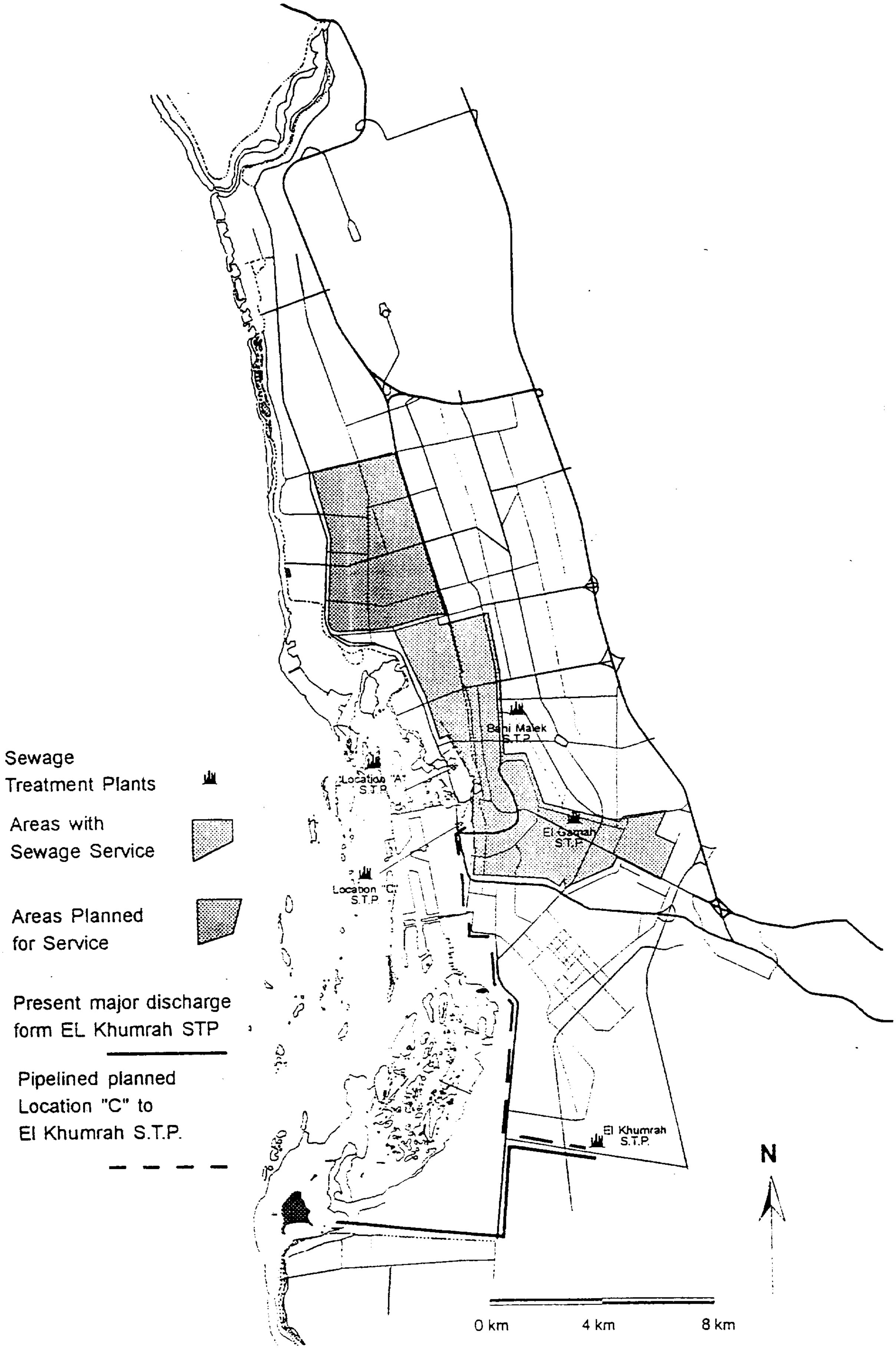


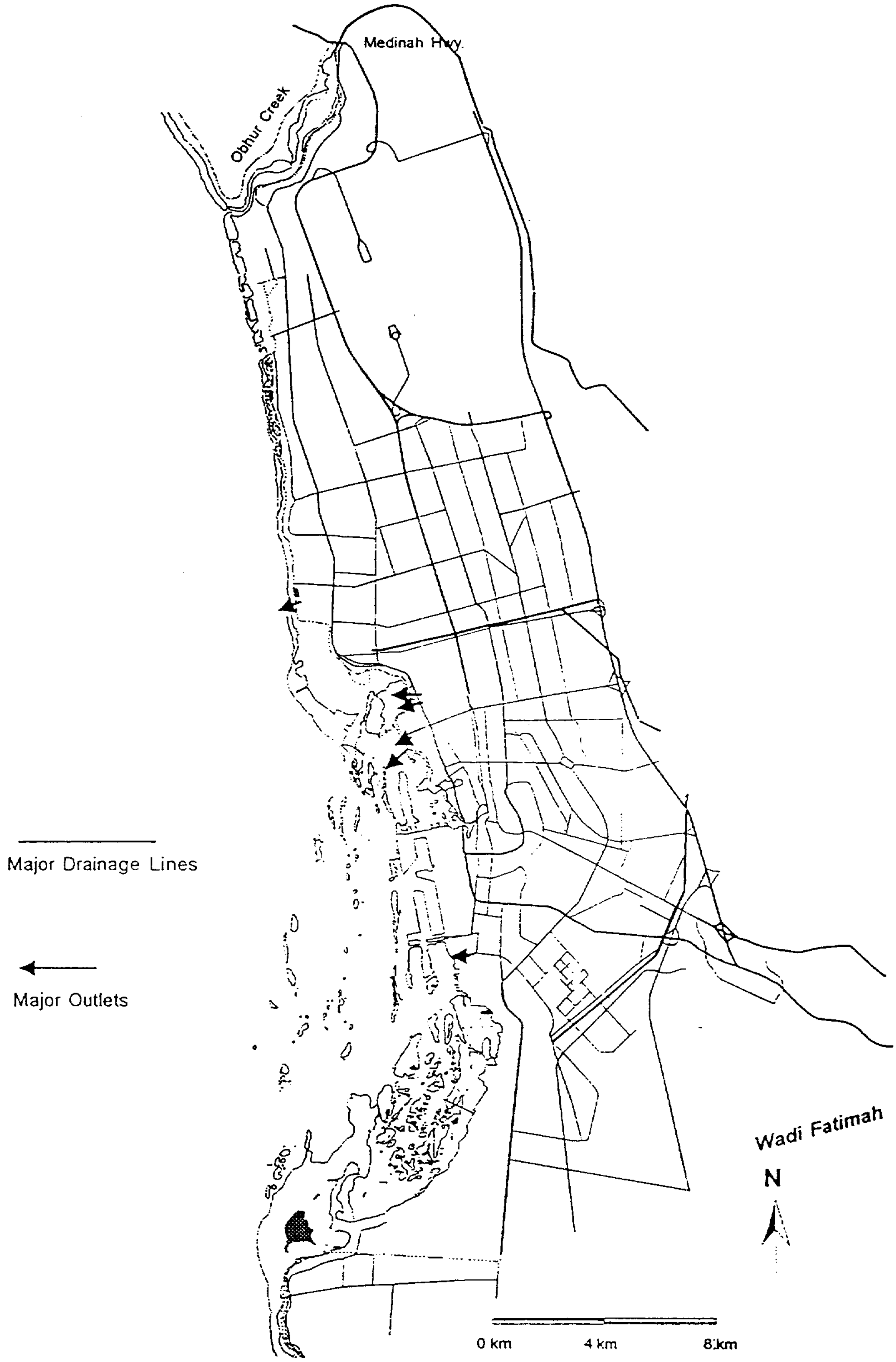
TABLE 15. INVENTORY OF SITES ALONG COAST DISCHARGING MATERIAL INTO THE SEA

Site No.	Source	Responsible	Pollutant	Action taken or responsible agent
1	El-Khumrah S.T.P.	Gov't	Treated sewage	Sanitation & Water
2	Naval Base	Gov't	Unknown	--
3	Jeddah Oil Refinery	Gov't	Unknown	Received notification
4	Jeddah Islamic Sea Port	Gov't	Overflow sewage	Received notification
5	Jeddah Islamic Sea Port	Gov't	Oil and grease	Received notification
6	Location "C" S T. P.	Gov't	Treated sewage	Sanitation & Water
7	Storm water exit "M"	Gov't	Undergroundwater	Municipality
8	Illegal discharges	Unknown	Untreated	--
9	Al-Salhiah Center	Private	Undergroundwater	--
10	Red Sea Palace Hotel	Private	Untreated	--
11	Storm water exit #11	Gov't	Untreated	Municipality
12	Freezer company	Private	Untreated	--
13	Fish market	Private	Washing water	Received notification
14	Coast Guard Station	Gov't	Untreated	Coast Guard
15	Location "A" S T. P.	Gov't	Treated	Sanitation and Water
16	Naval Institute	Gov't	Untreated	--
17	Mosques	Private	Untreated	--
18	Storm water exit #51	Private	Untreated	--
19	Air Defense Institute	Gov't	Untreated	Received notification
20	Military Hospital	Gov't	Untreated	Received notification
21	Desalinization Plant	Gov't	Sewage overflow	Received notification
22	Hovercraft center	Gov't	Untreated	Coast Guard
23	Al-Shalal restaurant	Private	Untreated	--
24	Saudia City desalinization	Private		--
25	Gahaza Center	Private	Untreated	Received notification
26	Al-Salamah and Al-Rawdah Districts	Gov't	Underground water	Sanitation and Water
27	Exit from Al-Salamah district	Gov't	Undergroundwater	Sanitation and Water
28	Al Bakri Compound	Private	Undergroundwater	--
*29	Housing area	Private	Unknown	--
30	Green Island	Private	Untreated	Received notification
31	Housing - Air Force staff	Private	Untreated	--
32	Mosque	Private	Untreated	--
33	Airport Desalinization	Gov't	High saline water	--
34	Private Residence	Private	Untreated	
35	Underground	Gov't	Undergroundwater	--
36 north	Housing compounds	Private	Untreated	Received notification
37 north	Gov't facilities 3	Gov't	Untreated	--

Source: Municipality of Jeddah, Engineering Department (report in Arabic).
* Actual location not mapped.

is the use of pumping stations to extract groundwater and discharge into the Red Sea. Groundwater extraction and disposal systems are already in limited use in Jeddah, but a large-scale operation would be needed to regulate the water table level in the whole city to levels that minimize the damages caused. Other remedies are reducing water use (including reducing water leakage from the water supply distribution system), and improving water collection, treatment, and disposal of wastewater.

Figure 23. Major storm drainage and discharges



The main duties of the Ministerial Committee for Environment are:

(a) To establish the Kingdom's position on environmental issues at the national, regional and international levels;

(b) To establish a National Environmental Strategy;

(c) To coordinate and follow up on environmental activities within the Kingdom.

Membership of the Ministerial Committee for Environment includes the Ministers of Agriculture and Water, Industry and Electricity, Finance and National Economy, Foreign Affairs, Health, Interior, Municipality and Rural Affairs, and Petroleum and Minerals, as well the president of the King Abdulaziz City for Science, and Technology (KACST) and the president of the Meteorology and Environmental Protection Administration (MEPA), who is designated as secretary-general of the Ministerial Committee for Environment. The Committee defers decisions that require the issuance of laws or legislative actions to the Council of Ministers.

The Committee is assisted by a Preparatory Committee (i.e. Environmental Protection Coordinating Committee) chaired by the Assistant to the Minister of Defence and Aviation. The Preparatory Committee also includes the Deputy Ministers of sectoral ministries as well as the President of MEPA. The Preparatory Committee is responsible for the development of studies and for recommending actions which are submitted for review and approval by the Ministerial Committee for Environment. The Secretariat provides logistic and technical support to the Preparatory Committee.

The central environmental protection agency in the Kingdom is MEPA, which was created in 1981, when the General Directorate of Meteorology (created in 1969) was renamed and given additional responsibilities. MEPA is part of the Ministry of Defense and Aviation. Its functions and responsibilities are:

(a) Conducting environmental surveys;
(b) Recommending environmental protection regulations;
(c) Preparing environmental standards;
(d) Assessing existing pollution levels;
(e) Recommending practical measures for dealing with emergency environmental plans;
(f) Keeping abreast of developments on the international level;
(g) Preparing and issuing climatological, environmental meteorological analyses;
(h) Forecasting and issuing bulletins in real time and non-real time format.

However, there are some other institutions which play important roles in environmental planning and management in the Kingdom. These include the following: National Commission for Wildlife Conservation and Development, King Abdulaziz City for Science and Technology, Ministry of Interior, Ministry of Municipal and Rural Affairs, Ministry of Petroleum and Minerals, (environmental activities undertaken by the two major operating companies Saudi ARAMCO and the Arabian Oil Company), Ministry of Agriculture and Water, Ministry of Health, Ministry of Planning, Arriyadh Developing Authority, and the Royal Commission for Jubail and Yanbu. Furthermore, there are some other institutions which play environmental support roles such as King Abdulaziz University, King Fahad University for Petroleum and Minerals (Research Institute), King Faisal University, King Saud University and Umm Al-Qura University (Center for Al-Haj Research).

MINISTERIAL COMMITTEE FOR THE ENVIRONMENT

CHAIRMAN :

H.R.H SECOND DEPUTY PREMIER

MEMBERS :

MINISTER OF INTERIOR
MINISTER OF FOREIGN AFFAIRS
ASSISTANCE TO THE MINISTER OF DEFENCE & AVIATION FOR CIVIL AVIATION
MINISTER OF FINANCE AND NATIONAL ECONOMY
MINISTER OF PETROLEUM AND MINERALS
MINISTER OF AGRICULTURE AND WATER
MINISTER OF MUNICIPAL AND RURAL AFFAIRS
MINISTER OF HEALTH
MINISTER OF INDUSTRY AND ELECTRICITY
MINISTER OF PLANNING
PRESIDENT OF KACST
PRESIDENT OF MEPA : *SECRETARY GENERAL*

SECRETARIAT
MEPA

ENVIRONMENTAL PROTECTION
COORDINATING COMMITTEE
EPCCOM
(PREPARATORY COMMITTEE)

CHAIRMAN:
PRESIDENT OF METEOROLOGY AND ENVIRONMENTAL PROTECTION ADMINISTRATION (MEPA)

MEMBERS ; DEPUTY MINISTRIAL LEVELS REPRESENTATION FROM
MINISTRY OF AGRICULTURE AND WATER
SAUDI ARABIA STANDARDS ORGANIZATION
MINISTRY OF COMMUNICATION
MEPA
MINISTRY OF HEALTH
MINISTRY OF INDUSTRY AND ELECTRICITY
MINISTRY OF INTERIOR
MINISTRY OF MUNICIPAL AND RURAL AFFAIRS
KACST
NATIONAL COMMISSION FOR WILDLIFE CONSERVATION AND DEVELOPMENT
PORTS AUTHORITY

Figure 24. The set-up of the Ministerial Committee for the Environment and the Environmental Protection Coordinating Committee

(m) Large organizations and bodies are directed to use salt reduction techniques with the aim of reducing dependence on undergroundwater, which is to be used in areas along the Red Sea and the Gulf.

(n) Nationwide campaigns will be carried out to educate and make the public aware of the importance of water saving.

(o) Scientific research aimed at finding additional sources to benefit from wastewater is being encouraged.

D. WATER PROTECTION

(a) Regulations on the protection of public utilities were issued by Royal Decree No. M/62 dated A.H. 1405 (1985). The regulations imposed fines and penalties, including imprisonment, for polluting water or other environmental resources by disposal of waste oil, batteries, industrial or construction waste, hazardous waste, or other pollutants affecting water or soil.

(b) In accordance with its charter, MEPA issued an initial set of Environmental Protection Standards in A.H. 1402 (1982). The document includes source and ambient standards designed to protect air and water quality by limiting the emission of pollutants from sources and the concentration of pollutants in air and water. The standards apply to all existing and planned facilities, both public and private, including industrial projects, transportation facilities, commercial and agricultural activities, sewage treatment plants, and human settlements within the Kingdom.

(c) MEPA has currently prepared a draft revision of Environmental Protection Standards—Water Quality Standards applying to all inland surface waters and all wastewaters discharged in the Kingdom of Saudi Arabia. They include performance standards for direct discharge, receiving water guidelines and pretreatment guidelines for discharge into central treatment facilities.

(d) The Royal Commission for Jubail and Yanbu has a Memorandum of Understanding with MEPA to act as the representative of MEPA in their areas of jurisdiction in Jubail. Industrial cities have also developed their own standards based on MEPA standards. The Memorandum of Understanding stresses that standards developed by the Royal Commission either should be the same or should be more stringent than MEPA standards.

(e) The Water and Sewerage Authority, under the Ministry of Municipal and Rural Affairs, also developed pretreatment guidelines on discharge to sewage treatment plants.

(f) The Ministry of Agriculture and Water has circulated draft irrigation water standards and the Royal Commission for Jubail and Yanbu, Jubail Project, published irrigation water concentration limits for treated wastewater. The Ministry of Agriculture and Water also developed draft concentration limits of various trace metals in sludge from wastewater treatment plants to be used in agriculture.

(g) A draft of national regulations governing wastewater has been prepared. It concerns effluent water drained into the wastewater network, treated water and methods for disposal or reuse of wastewater.

VII. RECOMMENDATIONS REGARDING WATER POLLUTION IN SELECTED URBAN AREAS IN THE ESCWA REGION

A. WATER POLLUTION CONTROL IN DAMASCUS

With regard to controlling the major sources of pollution, government strategies and plans have gaps where assistance is needed (table 15). Specific progress should be achieved in 1997 with the completion of the Damascus Wastewater Treatment Project. Various studies addressing the issues not covered by current plans are summarized below.

1. *Data gathering and analysis*

The Government has experience in data collection and is currently using the data it compiled on water quality in the Barada River to point out the effects of domestic wastewater on surface water quality. Long-term monitoring of groundwater such as that recently commenced by the Water Pollution Control Department will also provide useful planning information. In order to make informed decisions about the most urgent pollution control measures, a comprehensive programme monitoring water quality is needed, especially on pollution of groundwater from both industry and agriculture. Training should include instructions for technicians and planners on how to collect, present and use data for planning purposes and for advocating pollution control measures.

A comprehensive review of industry, including water use, wastewater treatment and disposal and disposal of industrial solid waste could help to develop an overall plan for dealing with industrial pollution and serve as a model for studies to be carried out in other countries in the region where industrial pollution is gradually becoming a greater threat to the environment.

Specific technical training is needed for laboratory technicians in the Water Pollution Control Department on how to use their atomic absorption unit for testing for heavy metals.

2. *Developing enforceable national legislation*

One of the major obstacles to controlling water pollution in Damascus is the lack of enforcement powers in current water pollution legislation, especially in the case of industrial pollution. A recent ESCWA conference on water legislation pointed out this need and provided guidelines for developing and approving national legislation. Continuing regional and national efforts on this issue could provide the assistance needed for the Syrian Arab Republic to pass the appropriate legislation.

3. *Training in industrial solid and liquid waste treatment and disposal*

Regional and/or national workshops for technicians and managers on industrial wastewater treatment options, including low-cost treatment solutions and cost-benefit analysis, are needed. A workshop at higher levels of government, perhaps on a regional level, could assist in promoting this subject and encouraging support for industrial control and treatment at the highest levels.

4. *Wastewater treatment and reuse*

Although it has been stated that the treated effluent will be of sufficient quality for irrigation, the issue of removing helminths from wastewater remains to be addressed. The subject of physical, social and

TABLE 16. WATER POLLUTION CONTROL IN THE DAMASCUS BASIN—OVERVIEW OF THE PRESENT SITUATION

Source of pollution	Disposal	Pollutes	Solution	Government strategy/plans	Gaps
Rural domestic wastewater	Directly to river or dumped by tankers	Surface and groundwater	Delivery by tankers to STW or development of small WW treatment systems for villages	Environment Strategy will address--1997	Assistance will be needed with detailed plans and implementation. Regulatory legislation Water quality data needed
Urban domestic wastewater	Via sewer to river	Surface water	Treatment works and reuse	Phase I--Damascus Wastewater Treatment Project--1997 WHO/CEHA training of wastewater engineers--1996 Environmental Impact of STW-funded by World Bank-1997	Quality criteria for treated sewage--will it be safe for irrigation? Not all of Damascus covered by sewerage network.
Urban domestic wastewater	Infiltration to groundwater	Groundwater	Upgrade sewerage network	Ongoing	
Agriculture irrigation water	On crops	Fruits and vegetables	Use treated water to FAO standards	Partial coverage through Damascus Wastewater Treatment Project. Government of Japan- Master plan for wastewater treatment and reuse--1997.	Coverage by WW treatment project only partial. Assistance with farmer training in WW reuse.
Agriculture wastewater	Seepage and overflow	Groundwater and surface water	Control use of agrochemicals.	FAO and ACSAD--increase agricultural production and irrigation efficiency.	More data needed on water quality and use of agrochemicals Programme to reduce use of agrochemicals. Regulatory legislation.
Industrial wastewater	Directly to river and inflation into ground	Surface and groundwater	Develop on-site treatment Relocation of industry	UNEP-feasibility for tannery effluent 1997. INWARDAM-Regional training on industrial water pollution management-1996. -Relocate industry to Adhra Industrial Zone.	Regulatory legislation Data on water quality Treatment of polluted water before it goes to STW Expertise in treatment of industrial waste.

Notes: WW=wastewater; STW=solid treated wastes; WHO/CEHA = World Health Organization Centre of Environmental Health Activities.

5. *Use of agrochemicals in agriculture*

A detailed assessment is needed of water quality and health risks resulting from overuse of agrochemicals. Viable economic alternatives need to be developed for farmers to replace their present practices of using more and more of the same toxic chemicals to fight pests and improve production.

C. WATER POLLUTION CONTROL—ACTION MEASURES

1. *Pollution load assessment*

As a part of its Technical Cooperation Programme, the Ministry of Finance and National Economy of Saudi Arabia requested the World Bank to provide advisory services to MEPA, for the preparation of Saudi Action Programme.

The major objectives of the Action Programme are to assist in strengthening environmental management in the Kingdom. One of the Action Programme activities includes the preparation of a "pollution load assessment" to assist in understanding the causes and effects of environmental degradation and in identifying priority environmental activities and the means to manage them. To this end, MEPA jointly with the World Bank, under the sponsorship of the Ministry of Finance, recently completed the "pollution load assessment".

The specific objective of the report on pollution load assessment is to estimate the order of magnitude of various pollutants emitted/discharged and the hazardous waste generated throughout the Kingdom by major industrial or municipal facilities. The mass of various pollutants of municipal and industrial origin Kingdom-wide were estimated, based on the real data provided by the concerned agencies and organizations, calculations based on mass balances, and the use of internationally established and accepted emission factors.

2. *Jeddah city file*

The rapid urban development which took place in the Kingdom of Saudi Arabia during the last two decades has resulted in an increase in the rate of pollution emission sources in most of the Kingdom's urban centres. This consequently led to a need for detailed knowledge of the quality of air, water and waste generation in the Kingdom. With such knowledge, it will be possible to assess the impact of pollution emissions on human health and the environment; monitor compliance with the national environmental standards, especially those promulgated by MEPA; and determine the available pollution control options.

With this in mind, MEPA prepared a long-range plan for executing a big project, the Environmental City File aimed at analysing, recording and archiving the data on various pollutant parameters at source of discharge and in the ambient environment (air and water) in the city under investigation. This project was planned to include most of the Saudi Arabian cities. However, as a first step to achieving this, in 1995 MEPA started the Jeddah city file which includes the evaluation and assessment of major sources of air pollution emissions; monitoring and assessment of major water discharge sources and their impact on the quality of sea water and groundwater; and quantification of hazardous waste generation and methods of disposal.

have been authorized by MEPA to carry out their own environmental programmes in the areas of their jurisdiction.

6. *Future plans and programmes*

The following are some of the programmes, on water pollution control which will be undertaken by MEPA: (a) review and finalize the draft of "Water Quality Standards"; (b) prepare guidelines for methods of water and wastewater analysis, which will be part of the previous item; (c) prepare pollution control and disposal guidelines for the following industries: tanneries, electroplating, food-processing plants, refineries, fertilizer industry, paper factories, textile industry, industrial waste treatment plants, and municipal wastewater plants; (d) prepare guidelines for the cooling water temperature control in refineries, desalinization plants and power stations; and (e) study the current situation for water and wastewater in the city of Riyadh.

7. *Proposals*

The water balance in the Jeddah area, that is the supply, use and removal of water, has changed rapidly with the growth of Jeddah. In the early history of the city, water was a scarce and expensive commodity. The natural environment could not supply the city's needs through rainfall and groundwater. Over the last 15 years, significant infrastructure has been established to provide residents throughout the city with a dependable water supply. Today, however, the increased volumes and mixed contents of the wastewater that must be disposed of, are greater than the environment's natural ability to assimilate it whether treated or not.

The supply of fresh water to the area comes from the desalinization of sea water from both the large plant and many smaller facilities, and from the natural supplies of rain in the watershed east of Jeddah. The disposal of large volumes of used and often polluted water through natural drainage and man-made engineering works is difficult and expensive to manage. The local geological structures and natural channels that had in the past handled the natural run-off have been altered significantly by human settlement, and filling and dredging activities along the coast. Changes in the natural drainage have also had wide-ranging effects on the city's groundwater, storm water drainage and sewerage systems, and the marine environment. This in turn has had cumulative impacts on the natural, social and economic environment of Jeddah.

Past and present disposal of natural and used water from domestic and industrial users has created unacceptable conditions in downtown Jeddah and in the marine areas. It is now expensive to fix these conditions. With continued urban expansion, disposal plans, which take into account the earlier problems encountered, need to be made. New environmental and socio-economic consequences of developmental decisions must be anticipated.

8. *Proposed recommendations for national adoption*

The following measures should be taken:

(a) Inter-agency coordination for water management in the city should be improved through the establishment of a coordination office in the Municipality of Jeddah or the office of the Governor of Mecca. The initial functions of this office would be to gather and exchange information about programme plans, studies, and implementation of programmes.

(a) Preparation of a water resource strategy;

(b) Development of policies and administrative measures for the constitutional enforcement of adapted environmental legislation;

(c) Formulation of environmental indicators and/or indices for water quality;

(d) Design of administrative routines for environmental inspections, auditions, investigation and proceedings for reporting corrective actions to alleviate noncompliance with environmental regulatory agencies.

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PART TWO

ENVIRONMENTAL IMPACT OF BRINE DISPOSAL ON INLAND AND OFFSHORE ENVIRONMENTS*

* References for part two are cited in the text by numbers enclosed in parentheses; the corresponding complete references are provided in the references to part two.

VIII. IMPACT OF BRINE DISPOSAL ON THE OFFSHORE MARINE ENVIRONMENT

A. BACKGROUND

ESCWA member States are mostly devoid of large rivers (except for Egypt, Iraq, Lebanon and the Syrian Arab Republic). These States have harsh climates, and suffer from high rates of evaporation. They are experiencing accelerating economic growth with significant urban expansion. They depend mainly on limited fossil and/or rechargeable groundwater and non-conventional water resources to meet their requirements. The problem of water shortages has been complicated by the high growth rates of the indigenous population in some member States and by the successive waves of foreign settlers attracted by the wealth of the oil reserves discovered in the Gulf region.

Owing to such a rapid increase in demand for water in the ESCWA region, where conventional water resources such as fresh surface water and renewable groundwater are extremely limited, other alternatives such as wastewater reclamation and desalination have been adopted since the 1960s. Additional but less realistic non-conventional water resources alternatives, encompassing iceberg towing, transport by large tankers, and towing using large-capacity rubber (Medusa) bags, have been considered.

Transporting water across international boundaries cannot be politically or economically justified. The Peace Pipeline proposed by Turkey to deliver 2.5 mcm of water to many cities in the Arabian Peninsula at a capital cost estimated at $20 billion is considered by some experts as too expensive and impractical. At the same cost (using 1993 prices), it is possible to build a number of desalination plants and the electric power plants required for their operation to produce potable water at a capacity of 7.5 mcm/day. Considering the political instability of the region, major concerns regarding the guaranteed life of transboundary projects would arise. Furthermore, ocean shipping by using tankers or Medusa bags cannot compete with large-scale desalination processes. When all associated costs at terminal points are considered, desalination usually costs only a fraction of the cost of ocean shipping.

Transportation of icebergs may still be considered as a cost-competitive, non-conventional water resource. However, the very high capital cost in addition to the constraints associated with its untested and pioneer application again make desalination as the technology of choice. A review of non-conventional water production schemes in the Arabian Gulf indicates that desalination and water reuse (in that order) are the most cost-effective ways to deal with water shortages (1). Currently, desalination technology has been perfected to the point where it can provide a reliable source of water at competitive costs. In the ESCWA member countries, desalination from dual-purpose plants (co-generation) has proved to be a more economical alternative than constructing new dams or extending pipelines to convey water from basins located in other regions. This is particularly true when required water quality standards, social acceptability and political vulnerability are taken into consideration.

The number of desalination plants in operation (as of 1992) had reached a total of 44, with 23 in Saudi Arabia, 8 in the United Arab Emirates, 6 in Kuwait, 3 in Bahrain, and 2 each in Oman and Qatar. Out of 15.58 mcm per day of worldwide installed desalination capacity, Gulf Cooperation Council (GCC) countries are responsible for almost half (49.5%) of the total. Saudi Arabia alone houses about half of the GCC desalination capabilities, amounting to about 25% of the world capacity. On the global level, the West Asian countries produce (as of December 1995) close to 52% of the world's desalinated water by utilizing only 13.2% of the total desalination units in the world of over 500 m^3/d capacity (2).

the feed water, the desalination technology used, the percentage of recovery, the chemical additives used within the process, the construction material, and the proficiency of the operators.

C. BRINE DISPOSAL IN THE OFFSHORE MARINE ENVIRONMENT

Most of the large-scale desalination plants in the ESCWA region are located on the coastlines of the Gulf, the Red Sea, and, to a much lesser extent, the Arabian Sea. They discharge their brine concentrate into the areas adjacent to the shore. According to the 1997 Saline Water Conservation Corporation report (4), not many studies on the impact of brine disposal on the living resources and environmental quality of the sea adjacent to desalination plants in the ESCWA region have been carried out. However, realizing the need for such a database for planning and management of the coastal environment, national institutions concerned with this industry have drawn up strategies for initiating programmes designed to understand and solve the potential environmental problems resulting from desalination. Substantial but fragmented and non-concerted efforts were carried out in Bahrain (5), in the United Arab Emirates in Abu Dhabi (6, 7, 8), as well as Kuwait (9, 10, 11, 12), and Saudi Arabia (4, 13, 14) to study and control the environmental impact associated with brine water disposal into the offshore environment of the ESCWA region. The Research and Development Centre of the Saline Water Conservation Corporation at Al-Jubail in Saudi Arabia has paid greater attention and initiated integrated environmental studies on the environmental impact of the desalination industry. These studies are expected to reveal valuable and seriously needed data on the effect of brine water disposal on the offshore marine environment in particular.

Conceptually, it is believed that rapid mixing and dilution are the "keys" for the safe disposal of brine in the sea. In 1995 Wenner and Feo (2) noted that the most common and least expensive method of brine disposal is discharge into the ocean. They also noted that owing to its relatively higher density, discharged brine concentrate will sink and descend to the bottom, which leads to its potential diminishment through mixing with the surrounding ambient sea waters. In 1997 Mandil (3) noted that the environmental impact of brine discharge depends to a large extent on the physical, chemical and biological characteristics of the receiving offshore marine environment.

The most common feature noted in large-scale desalination plants is that their feed water intakes are surface and sometimes extended offshore with specially designed protective structures. However, the outfalls intended for the discharge of brine and cooling waters are ordinarily surface and nearshore. Whenever the feed water intakes and the brine water outfalls are adjacent, it is likely that under certain fluctuating hydrographic conditions, brine water might reach the feed water intakes, leading to lower operational efficiency and recirculation of some of the discharged pollutants. In general, large and modern desalination plants have sound designs for their intakes and outfalls to ensure more efficient operation and to avoid the passage of discharged effluents to the feed water intakes. According to the Saline Water Conservation Corporation (4), the largest desalination plant in the world at Jubail has a well-segregated intake forebay and outfall to minimize the potential contamination of feed waters with the discharged brine concentrate. The outfall bay is designed to achieve maximum mixing and dispersion of the discharged brine prior to its dissipation in the open sea. The Doha East, Doha West and Al-Zour power desalination plants in Kuwait (9), and the Al-Taweela Desalination plant in Abu-Dhabi (6) have modern and carefully segregated intakes and outfalls.

The amount of salty feed water that must be provided to the desalination plants for each unit of product water is an important environmental consideration. According to ESCWA research (16), sea water reverse osmosis will consume 2-3 cu m for each cu m of product water. However, distillation processes would typically

The preliminary results gathered and reported by the Saline Water Conservation Corporation (4) in Saudi Arabia indicate that the changes in the physico-chemical characteristics of the sea water in the outfall mixing bay of the desalination plants on the Gulf were much lower than the values reported elsewhere from the Gulf and from Aqaba. The rapid mixing and dispersion of the brine reaching the mixing bay were considered as the main reasons for the very low variation in these parameters.

It is safe to assume that the increase in salinity of the open sea water in the vicinity of large sea water desalination plants has been overstated and should not give reasons for concern, particularly when offshore hydrographic circulation patterns are taken into consideration in the design of the discharge outlets of plants.

2. *Environmental impact of increased salinity on a semi-enclosed marine environment*

The discharge of brine water in shallow and relatively stagnant nearly land-locked coastal areas such as bays, *khours* (depressions), and harbours, could result in a more pronounced impact on the encircled marine environment. Werner and Feo (1995) warned that the unlimited disposal of brine waters in sheltered bays or harbours might lead to serious effects on the local marine habitat. One of the earliest works (in 1975) which emphasized the biological impact of a desalination plant was that of Cheshire (17), who reported adverse effects of brine discharge on the fauna and flora of Safety Harbor, receiving effluents from the Key West desalination plant in Florida, United Sates. Cheshire reported the near disappearance of a variety of marine organisms during the 15-month course of his field investigations. Sea squirts, various species of larvae, bryozoans and sabellidae worms were absent during certain periods. Dead shells of various clams and oysters were abundant in the area studied. Later, Foskett (18) revealed that larval mortality, slow development rate, failure of osmoregulatory mechanisms, shrinkage of body cells, and malfunction of the endocrine system, are a few of the adverse effects observed in marine organisms exposed to elevated salinities.

The percentage of recovery attainable from the desalination of sea water ranges from 20% to 65% (16), depending on the process used in the desalination, giving rise to a concentration ratio of 1.25 to 3. It is important to note that higher recovery reduces the volume of brine water discharged, yet it will increase the salt content by the same ratio. Reciprocally, lower recovery will reduce the salt content and increase the volume of brine water discharged. In this respect, it is the mass of the discharged salt that counts rather than its concentration per litre.

Semi-enclosed and shallow embayments in the Gulf are naturally characterized by a higher salt content owing to the accelerated rate of evaporation, lack of freshwater discharges and restricted dispersion and dilution. In some offshore localities, particularly in the Gulf, the average salinity in summer can reach 48 parts per thousand (ppt), as compared with 37 ppt in winter. According to MEPA (14), some embayments bordering the coast of the Gulf are characterized by higher levels exceeding 70 ppt. This prompted Sheppard in 1993 (19) to suggest that the biota in many cases are living on the extreme limits of their environmental tolerance. However, it sounds reasonable to suggest that the endogenous biota have adapted to the naturally prevailing environmental conditions characterized by high salinity. The high salt content, in addition to the natural cycles of even higher salinities, might have several orders of magnitude. Very limited environmental impacts have been documented associating natural cycles of higher salinity with negative ecological implications. Hence, the slight increase in salinity in the proximity of points of brine water discharge is projected to be of limited impact on the semi-enclosed marine ecology.

The hypobromous acid will dissociate as does hypochlorous acid, depending upon the pH, temperature and ionic strength. The reaction rate between chlorine and bromide ion is very rapid. The time required for the reaction to proceed to convert 99% of the injected chlorine into bromine at 25^{o} C temperature and pH of 8.3 is less than 10 seconds.

The discharge of residual chlorine oxidants is exclusive to desalination processes other than SWRO. It is a common practice to dechlorinate the feed water to SWRO to avoid detrimental impacts on the RO membranes.

In the Umm Al-Nar power desalination plant in the United Arab Emirates, 1,600 tons of chlorine are poured into the intake lagoon (8).

In an effort to control biofouling in Kuwait, chlorine is added continuously at the desalination plants intakes at concentrations ranging from 2 to 4 ppm. Shock doses are also added every 8 hours for 20 minutes at 8 to 10 ppm. The common practice is to maintain a 0.5 ppm of residual chlorine at plant outlets to avoid any risk associated with biofouling (11). However, owing to the relatively high chlorine demand of the feed sea water and the high ambient temperature, the levels of total residual chlorine actually discharged into the sea are regularly in the range of 0.1 ppm.

The discharge of residual chlorine even at very low fractions of one ppm levels have come under fire by environmentalists owing to their detrimental and toxic implications on the offshore marine environment (22). According to USA-EPA, (1986), fish and invertebrates are more sensitive to residual chlorine oxidants than aquatic plants.

Shams El-Din and others reviewed the environmental impact of brine water discharge on the offshore marine environment of the UAN power desalination plant in Abu Dhabi (8). They attributed the destruction of some of the near-bottom marine life to the hypochlorite (actually hypobromide) ion produced as a result of chlorination. Al-Awadi in 1995 stressed the fact that the presence of trace metals and free residual chlorine in discharged brine water should be a matter of environmental concern (9).

Even though chlorine is considered the most economical and effective antifouling measure, its usefulness has been significantly compromised by stringent discharge regulations in the developed world (12).

Sander and Ryther in 1979 demonstrated a large shift in marine phytoplankton species composition by exposure to chlorine. In the same year, Seegert found that fish were absent in water plumes having total residual chlorine > 0.05 ppm (25). Active avoidance was observed in several large schools of fish that would occasionally enter the chlorinated plume only to return rapidly to their original position in the unchlorinated water. Khalansky and Bordet in 1979 observed a reduction in the muscle filtration rate in response to oxidizing compounds, which resulted in a decrease in the growth rate related to the amount of food available in sea water (26). Eppley and others in 1976 noticed a decrease in photosynthesis of marine phytoplankton at 0.04 and 0.02 ppm of residual chlorine(27).

Given these facts, it appears that the discharge of trace levels of residual chlorine oxidants either in open or enclosed sea waters will be very detrimental to aquatic life in the offshore marine environment.

Most of the environmental studies to investigate heavy metals pollution of the offshore marine environment, caused by the discharge of brine water, have unfortunately failed to establish or confirm causality. This failure is mainly attributed to the multitude of landbased industrial sources situated near the coastal lines in the ESCWA region, which release much higher levels of heavy metal into the offshore marine environment than the desalination industry.

In the United Arab Emirates in 1994, Shams El-Din and others observed that the discharged brine from the UAN power desalination plant in Abu Dhabi carried measurable quantities of Cu, Ni and Manganese (Mn) resulting from the corrosion of metal tubes, water boxes and flash chamber wall material (8). They also noticed a rise in the concentration of these metals in the brine during the process of acid wash of distillers.

In 1997 Saudi Arabia, research on heavy metals (Cu, As, Pd, Ni and Fe) was carried out by the Saline Water Conversion for sea water feed, the mixing zone and the recovery zone in the offshore waters of Al-Jubail desalination plant, as shown in table II.2. It is important to note that the extremely low concentration values obtained for these heavy metals in the samples collected from the three sites are comparable within experimental error. However, in this respect, it is important to recognize that owing to their cumulative and conservative nature in the marine sediment (as their ultimate sink), metals in the sediment matrix would have been a much better environmental indicator for tracing the fate and transport of heavy metals in the marine environment.

According to Manna (1994), the principal pollutants present in the brine effluent discharged from dual purpose plants in Saudi Arabia are metal ions of corrosion origin such as Cu, Ni, Zn and Chromium (Cr).

As conservative pollutants, metals will last in different compartments of the marine environment forever. However, their ultimate sink is the marine sediment. The level of metals primarily in sediments and to a much lesser extent in sea water reflects the general status of the environment, but not necessarily the biological availability of these metals.

After nearly 20 years of practising large-scale seawater desalination, studies conducted offshore from Kuwait revealed that local fish and shrimp species were not contaminated by heavy metal (33).

Fortunately, most of the reported data indicate that the levels of heavy metals associated with brine water disposal are minimal and often below the detection limits of the standard analytical procedures. This has been particularly true after blending of brine water with large volumes of cooling water used in power production. When comparing the mass and nature of heavy metals released with brine water to the amount of heavy metals being released from land-based industrial wastewater, atmospheric fallout and crude oil spills, they are thought to be negligible.

7. *Environmental impact of anti-scalants in brine water*

The chemical analysis of sea water in the ESCWA region indicates that scale such as alkaline scale can form in the desalination plants. These scales occur when the bicarbonate ion breaks down by heating as follows:

$$2HCO_3^- = CO_2 + H_2O + CO_3^{2-} \quad \text{.........} (2)$$

$$HCO_3^- + H^+ = CO_2 + H_2O \quad .... (5)$$

Unfortunately, the addition of H_2SO_4 leads to the formation of mainly insoluble calcium and to a lesser extent barium and strontium sulphate scales according to the following reaction:

$$CaCO_3 + H_2SO_4 = CaSO_4 + H_2O + CO_2 \quad .... (6)$$

The solubility of the sulphate salts in seawater decreases with the increase of temperature and concentration of Ca^{++}. Another problem connected with the precipitation of $CaSO_4$ is that the compound is not readily removed from the heat exchanger tubes by normal acid wash.

<u>Environmental impacts of acid additions</u>: The extremely large carbonate buffering capacity of the sea water minimizes the impact of acids on the environment and renders it negligible. Al-Tayaran and Madany were unable to detect any discernible pH variation in offshore seawater in the proximity of the Sitra power and desalination plant in Bahrain (5).

A threshold scale inhibitor such as mixtures of sodium hexametaphosphate and surface active agents such as lignin sulphonic acid derivatives and esters of polyalkyl glycols are added at a dose ranging from 4 to 6 ppm to hamper the growth of carbonate and/or sulphate crystals. These polyphosphates are effective only at temperatures lower than 90^o C. They are commercially available under various trade names such as Hagevap, Albrevap and Salvap.

For higher temperature scale inhibition, other agents have recently appeared on the market under commercial names such as Belgard EV, Belgard EV2000 and Flocon 247. These are mainly polymers of organic acids such as maleic anhydride and acrylic acids.

<u>Environmental impacts of scale inhibitors</u>: The greatest environmental impact of polyphosphate in reject brine on the offshore marine environment lies in its nutritional value. When present with other nutrients, phosphate causes an overabundant growth of plants that are unusual or non-indigenous to the area. This excessive plant growth usually means a reduction in diversity of species, and results in an imbalance of food chain materials essential for intermediate organisms. In turn their demise means an increase in BOD and turbidity of water.

In the United Arab Emirates in 1994, Shams El-Din and others (8) researched the impact of utilizing polyphosphate-based additives to inhibit the formation of alkaline scale in the condenser tubes of the distillers. During the operation, part of the chemical was lost by absorption on scale crystallites and the remainder found its way into the discharge basin. Being a ready source of phosphorus, the additive caused the flourishing of algae as green mat near the outfall. The increase in the mat thickness was found to cause dissolved oxygen depletion in the receiving offshore sea water. Shams El-Din described the new generations of additives currently in use. Organic polymers based on maleic anhydride monomer, did not cause any algal growth in the discharge bay of the UAN power desalination plant.

Table II.3 as extracted from SWCC (1997) is providing the percentage distribution of zooplankton at the feed water zone and the outfall mixing zone of a desalination plant in Saudi Arabia. SWCC (1997) noted that most of the zooplankton organisms provided replacement generations in a matter of hours/days (e.g. copepoda) in favorable environmental settings.

A decrease in bivalves (7.9%) along with an increase in the percentage of protozoa and Copepoda was found in the outfall mixing bay. The Saline Water Conversion Corporation attributed the observed drop in percentage composition of polychaeta, cirripedia, pteropoda and appendicularia to physical and chemical stresses endured by zooplankton within the desalination process.

The effect of brine disposal on the offshore marine environment was categorized as mainly due to the impingement, entrainment and entrapment effects within the desalination process rather than due to the effect of brine concentrate itself on the marine biota.

D. ENVIRONMENTAL MEASURES FOR THE CONTROL OF BRINE WATER DISPOSAL IN THE OFFSHORE MARINE ENVIRONMENT

In most of the cases, high salinity reject brine is simply returned to the offshore marine environment. This is the least expensive and most widely followed practice in the desalination industry in the ESCWA region. In sites where small plants are located, the brine disposal has not caused any contamination of the offshore marine environment.

Several methods have been suggested to alleviate or minimize the impact of reject brine disposal on the offshore marine environment. Most of the suggested methods focused on making optimum use of tidal flushing, dispersion, and dilution and reducing the contaminants to stay within the assimilation capacity of the overall system. A matter of direct concern in this context has been the demarcation of brine-seawater mixing and recovery zones in the receiving water at each desalination plant site. Meanwhile, the introduction of treatment methods that greatly reduce the impact of reject brine on the marine environment should be considered.

The introduction of chemicals to control scale formation has witnessed significant technological advancements. Numerous polyelectrolytes (polymers) were developed and marketed to replace acids and polyphosphates as antiscalants. These polymers are claimed to be biodegradable and with much less lower environmental impact than polyphosphates.

The amount of heavy metal ions is directly related to the pH of the water, and the material used in the construction of the desalination machinery. Consequently, in order to limit the potential for adverse effects on offshore marine ecosystems, it is advisable to monitor closely and to control the pH of the water passing through the different stages of the process, and adjust it at the end so that its value at the discharge point becomes as close as possible to its value at the intake. Build-up of heavy metals in brine water should be prevented by using corrosion inhibitors or by using more resistant construction material. The level of heavy metals concentration in the effluent should be limited and depends upon the characteristics of the local environment. It appears at this stage that the major remaining problems associated with reject brine discharges are mostly thermal pollution and residual chlorine.

was found to be the most cost-effective and feasible technique for implementation (11). It is generally believed that dechlorination is beneficial, especially because it reduces acute toxicity (37, 38) and even mutagenecity (39) associated with chlorinated water. In addition, dehalogenation will prevent further formation of THMs in offshore.

The chemical reactions involved in the SO2 dehalogenation were given as follows:

$$SO_2 + H_2O \text{ ----------->} H_2SO_3 \text{ .... } (7)$$

The sulphurous acid reacts with the various chlorine residual (Bromine residual) species as follows:

$$HOCl + H_2SO_3 \text{ --------->} HCl + H2SO_4 \text{ .... } (8)$$

$$NH_2Cl + H_2SO_3 + H_2O \text{ --------->} NH_4Cl + H_2SO_4 \text{ ...... } (9)$$

$$NHCl_2 + 2H_2SO_3 + 2H_2O \text{ --------->} NH_4Cl + HCl + 2H_2SO_4 \text{ ...} (10)$$

$$NCl_3 + 3H_2SO_3 + 3H_2O \text{ --------->} NH_4Cl + 2HCl + 3H_2SO_4 \text{ ...... } (11)$$

The reactions prescribed by equations 7 to 11 are complete in a matter of less than 10 seconds. For each part of chlorine removed, 2.8 mg/l alkalinity as $CaCO_3$ is consumed. Theoretically, no significant physical or chemical degradation should be found in reject brine following dehalogenation using SO_2. Fig. II.1 provides a layout of the suggested dechlorination facility.

IX. IMPACT OF BRINE DISPOSAL ON LAND

A. BACKGROUND

In many instances, RO desalination plants are located at inland sites, where the disposal of reject brine is in some cases the most critical economic and environmental problem. In these inland locations, brackish groundwater resources are used as feed water for desalination. Brackish water reverse osmosis (BWRO) is used to desalinate groundwater of much lower salinity than sea water. Typically the TDS will range from 2,000 to more than 8,000 compared with 45,000 for sea water.

High salinity brine water resulting as a by-product from the desalination processes is considered one of the major factors determining the location, capital cost and operation cost of BWRO desalination facilities. The brine in the BWRO plant can amount to 20% of the water produced and, where it can be discharged to the sea or a smaller saline water body, it is generally not a problem. Ordinarily, the rejected brine cannot be disposed of economically to a distant sea or reused for agriculture or other applications and the brine disposal problem becomes a critical drawback in exploiting desperately needed brackish groundwater resources.

Brine reject, if not disposed of properly, has a good potential for polluting the same groundwater resources used as feed water for RO systems. High salt contents in reject brine can reach groundwater by percolation if improperly disposed of on land. Productivity of agricultural lands can deteriorate by the deposition of air-borne salts from dried brine. However, the environmental problems associated with thermal desalination, such as residual chlorine, heavy metals and thermal pollution, are not usually found in BWRO. Although conceptually there is an economic incentive to use a high recovery system to reduce energy consumption and decrease brine water volume, these advantages must be weighed against the disadvantages. The two major drawbacks are the increased sophistication of the RO system, including the complexity of pre-treatment of feed waters and the increased potential for fouling and scaling of membranes owing to precipitation of carbonates and sulphates. The potential for scale formation augments as the concentration of brine increases for each successive RO stage. This is, of course, highly dependent on the chemical constituents in each individual water resource and must be examined on a case-by-case basis. Apart from economics, other factors contributing to the desirability for investing in higher recovery include the scarcity of brackish groundwater resources.

Using the high recovery approach, Gluckestern and Priel (40) achieved a 92% recovery rate for a 300 m^3/h brackish groundwater by using a three brine stage BWRO system. A simplified diagram of the high recovery plant is illustrated in Figure II.2. Out of the 300 cu m, only 206 cu m of brackish feed is desalted. The limiting factor in this case was the 250% oversaturation of calcium sulphate in the reject brine. The total related water supply (following blending) amounts to about 284 m^3/h, and the disposed brine to 16 m^3/h.

B. ENVIRONMENTAL MEASURES FOR INLAND BRINE WATER DISPOSAL

Since the reject brine has the potential of causing serious environmental problems if discharged improperly, its disposal should be carefully considered. The necessity for special disposal techniques could make the system very costly. According to ESCWA (16), cost plays an important role in selecting the method of reject brine disposal. This cost ranged from 5% to 33% of the total cost of desalination. The cost has always been a function of the reject brine characteristics, the level of treatment before disposal, the means of disposal and the nature of the disposal environment. Gluckestern and Priel revealed that despite the differences in system capacity and feed water salinity, the total desalination cost for a typical inland BWRO desalination plant is much higher than that of a plant disposing of its reject brine into a nearby sea or lake (40).

to Gluckestern and Priel (40), for a typical 300 m^3/h BWRO discharging a reject brine of 16 m^3/h, the required evaporation pond area for 6,500 hours operation time is 65,000 m^2. The cost of brine disposal including land cost amounted to $0.85/cu m. Depending on the value and availability of land, properly constructed and managed lined evaporation ponds may cost more than deep well injection. According to ESCWA research (16), the concentration of reject brine into solid salts using solar evaporation may cost $1.15 to $1.88 per 1,000 gallons of desalinated water using 1985 United States dollar values. Gluckestern and Priel estimated the cost of disposal of reject brine in an evaporation pond at 15% of the total desalination cost.

2. *Deep well injection*

Disposal of reject brine by injection into deep wells has been successful in areas of low or non-existent assimilating water bodies. To be effective, the brine must be placed in a geological formation which prevents its migration to the surface or groundwater supplies. The rock types most frequently used are the more porous ones such as limestone, sandstone and dolomites, since the porosity may help develop a filter cake which plugs the well. Other factors to be considered are the depth and diameter of the well, injection pressure to be applied, and the volume and characteristics of the brine to be disposed. The BWRO design engineer should work closely with a geologist familiar with the subsurface formations in the area in order to select the proper reject brine disposal zone. A testing well should be drilled and core samples should be analysed for specific characteristics such as permeability and reactivity with the brine. Tests should be carried out to determine the injection pressure required at various reject brine flows. Certain procedures, such as fracturing and acidizing, may be used to improve the soil permeability and thus reduce the energy cost of the injection pressure required at various flows.

Reject brine may be injected into a downhole formation located at a minimum of 100 metres below the deepest fresh water sand into a dry porous strata separated from deep groundwater by a thick impervious layer. In theory, the reject brine pumped into the well soaks into the porous material and remains isolated from the groundwater by the impermeable overhead layer. It is important to note that it is impossible to guarantee that fractures in the impermeable layer resulting from earthquakes and strong vibrations will not eventually permit brine water to leak out and contaminate the groundwater. Stresses produced by the introduction of the reject brine may even cause such a fracture. Other ways in which brine can escape into strata containing fresh groundwater include corrosion of the casing and an inadequate seal following the boring of the well.

According to the Saline Water Conversion Corporation (4), the injection of waste brine into deep wells has been widely used by the oil and gas industries in the ESCWA region. Poots (41) revealed that brine reject disposal in deep wells is costly and emphasized the need for a comprehensive, site-specific techno-economic assessment of each proposal.

The estimated cost for the disposal of reject brine by deep well injection ranges from $0.10 to $1.15 per 1,000 gallons of desalinated water at 1985 United States dollar values (16).

3. *Disposal into surface water bodies*

Under certain conditions, discharge of brine concentrate into the sea might be one of the best and most cost-effective available alternatives. However, special consideration should be given to the siting of the point of discharge to avoid any detrimental impact on environmentally sensitive areas such as mangroves, coral reefs, nesting areas, sea grass areas and breeding areas. The outfall for brine disposal should avoid mud flats and should be selected at a point where offshore currents are significant to ensure maximum blending, dilution and dispersion of the released salts and make optimum use of tidal flushing.

X. REGULATORY ASPECTS OF BRINE REJECT DISCHARGE IN THE ESCWA REGION

A. BASIC CONSIDERATIONS

As far as could be ascertained by this study, the countries in the ESCWA region did not pass any environmental regulations to control the discharge of brine waters into the environment. Regulatory agencies in the United States have labelled brine concentrates as "industrial waste", classifying them with deleterious effluents discharged from industrial plants of all categories. The United States Clean Water Act has enforced the National Pollutant Discharge Elimination System under which it is unlawful to discharge pollutants from any point source into waters of the United States without obtaining a permit and complying with its terms. All water bodies in the United States, including lakes, rivers, streams, wetlands and territorial seas, extending up to three miles from the coastline, are covered under this system (Wenner and Feo, 1995).

The United States Environmental Protection Agency (15) and the Environmental Agency of the United Kingdom have already enforced regulations for brine concentrate disposal. Regulatory agencies currently allow the water quality confined to the area adjacent to the point of discharge to degrade to a limited extent. It should also be able to withstand certain minimum conditions defined by the environmental regulatory agencies. This area of water quality degradation is defined as a "mixing zone".

In a review on the status of brine disposal in the United States, Bene and others (45) revealed that the Environmental Protection Agency has adopted discharge rules to classify brine discharge, define mixing zones and determine dilution criteria based on the tolerance of the local biota to higher salinities. According to Kimes (46), the Florida Administrative Code does not permit "mixing zones" in nursery areas containing specific aquatic plants listed by the regulatory agency. In addition, desalination plants must submit data that provide reasonable assurance that the proposed brine discharge will be free from contaminants under the relevant rules of the Florida Administrative Code. In general, the concept of a Regulatory Mixing Zone (RMZ) for discharge of brine in surface water bodies is being widely accepted by environmental regulatory agencies around the world. The RMZ can be used to delineate the borders of the zone allowed for discharge. The RMZ concept could represent the proper response to the needs of the desalination plants for discharge regulations of brine reject into the surface water bodies in the ESCWA region.

B. GUIDELINES FOR WATER QUALITY FOR THE MANAGEMENT AND CONTROL OF BRINE DISCHARGE

The following are the water quality criteria of relevance to brine reject disposal in the marine environment as developed in 1986 by the Office of Water Regulations and Standards of the United States Environmental Protection Agency. These criteria are provided for use by the environmental regulating authorities in the ESCWA region as guidelines for the management and control of brine discharge in sea waters. The criteria provide guidance on the maximum acceptable levels of pollutants in the ambient environment of the receiving sea water.

1. *Residual chlorine*

Under the current regulations, mostly derived from the above-mentioned criteria developed in 1986, the discharge of residual chlorine in sea water should not have unacceptable effects if the four-day average concentration of chlorine-produced oxidants does not exceed 7.5 micrograms per litre, i.e. parts per billion (pbb), more than once every three years on average, and if the one-hour average concentration does not exceed 13 ppb more than once every three years on average. The recommended exceeding frequency of three years is the Environmental Protection Agency's best scientific judgement of the average amount of

(c) *Lead*

Except possibly where a locally important species is very sensitive, salt water aquatic organisms and their uses should not be affected unacceptably if the four-day average concentration of lead does not exceed 5.6 ppb more than once every three years on average, and if the one-hour average concentration does not exceed 140 ppb more than once every three years on average.

Three years is the Environmental Protection Agency's best scientific judgement of the average amount of time aquatic ecosystems should be provided between excursions. The resilience of ecosystems and their abilities to recover differ greatly, however, and site-specific allowed excursion frequencies may be established if adequate justification is provided.

(d) *Iron*

Waters may contain iron concentration of several ppm with little effect on aquatic life. There are no criteria for iron in salt water; however, fresh water aquatic organisms and their uses should not be affected unacceptably if the level of iron is less than 1 ppm on average.

(e) *Arsenic*

Except possibly where a locally important species is very sensitive, salt water aquatic organisms and their uses should not be affected unacceptably if the four-day average concentration of arsenic III does not exceed 36 ppb more than once every three years on average, and if the one-hour average concentration does not exceed 69 ppb more than once every three years on average. This criterion might be too high wherever *Skeletonema Cosrarum* or *Thalassiosira Aestivalis* is ecologically important.

Three years is the Environmental Protection Agency's best scientific judgement of the average amount of time aquatic ecosystems should be provided between excursions. The resilience of ecosystems and their abilities to recover differ greatly, however, and site-specific allowed excursion frequencies may be established if adequate justification is provided.

(f) *Copper*

The acute sensitivities of salt water animals to copper range from 5.8 ppb for the blue mussel to 600 ppb for the green crab. A chronic life-cycle test has been conducted with a mysid, and adverse effects were observed at 77 ppb.

(g) *Cadmium*

Except possibly where a locally important species is very sensitive, salt water aquatic organisms and their uses should not be affected unacceptably if the four-day average concentration of cadmium does not exceed 9.3 ppb more than once every three years on average, and if the one-hour average concentration does not exceed 43 ppb more than once every three years on average. The small amount of information available concerning the sensitivity of the American lobster to cadmium indicates that this important species might not be protected by this criterion. In addition, data suggest that acute toxicity of cadmium is salinity dependent; therefore, the one-hour average concentration might be underprotective at low salinities and overprotective at high salinities.

Three years is the Environmental Protection Agency's best scientific judgement of the average amount of time aquatic ecosystems should be provided between excursions. The resilience of ecosystems

XI. RESEARCH NEEDED AND RECOMMENDATIONS ON THE ENVIRONMENTAL ASPECTS OF BRINE REJECT DISPOSAL IN THE ESCWA REGION

A. RESEARCH NEEDS

The need for a regional concerted and coordinated research programme focused on the identification, assessment, management and control of the environmental aspects associated with brine reject disposal in the ESCWA region is fundamental. The similar environmental settings and comparable water scarcity problems faced by most of the ESCWA member States leave no choice for these countries but to consolidate their resources on an integrated research programme aimed at understanding and resolving the environmental uncertainties associated with water desalination. In their totality, the reported investigations on the environmental effects of brine reject disposal in the ESCWA region are inadequate. Meanwhile, owing to the lack of coordination among ESCWA member States, singular, fragmented, duplicated, and sometimes unnecessary, efforts and resources are wasted by having the same issues investigated by different institutions in different States.

The main objective of the proposed integrated regional research programme is to provide decision makers in the ESCWA region with a scientific basis for enforcing harmonized appropriate regulations and for taking action needed to control the environmental effects associated with brine reject discharge in the marine and inland environments. The specific objectives of the proposed research programme might include the following:

(a) Upgrading knowledge in the ESCWA region on the present level and trends of polluting substances originating from brine reject resulting from various desalination processes;

(b) Assessment of the potential transport, transformation and fate of the pollutants in the brine reject in relation to their chemical, biological and physical control processes;

(c) Defining the capacity of the receiving environment (marine and/or inland) for the assimilation and/or dissipation of the pollutants in the discharged brine reject;

(d) Determination of the impact of pollutants in the brine reject on ecosystems (marine and in-and);

(e) Identification of operational, mitigation and control measures intended to avoid, eliminate and/or minimize the environmental effects of brine reject discharges;

(f) Dissemination of the acquired information to all countries of the region for implementation.

B. CONCLUSIONS AND RECOMMENDATIONS

1. *Impact on the marine environment*

(a) The environmental impact of brine discharge depends to a large extent on the physical, chemical and biological characteristics of the receiving offshore marine environment.

(b) The characteristics of the reject brine directly depend on the quality of the feed water, the desalination technology used, the percentage recovery, the chemical additives used within the process, the construction materials and the proficiency of the operators.

(n) The extremely large carbonate buffering capacity of the sea water minimizes the impact of sulphuric acid (added to avoid carbonate scaling in the desalination plants) and renders it of negligible impact on the marine environment.

(o) In general terms, desalination had been practised in the ESCWA region for nearly three decades, the discharge of reject brine to the offshore marine environment did not cause notable environmental deterioration.

(p) The amount of heavy metal ions is directly related to the pH of the water, and the material used in the construction of the desalination machinery. Build-up of heavy metals in brine water can be prevented by using corrosion inhibitors or by using more resistant construction material.

(q) Chlorination followed by dechlorination using regenerated SO_2 emitted in the air from thermal power plants was found to be the most cost-effective and feasible technique to eliminate the deleterious environmental impact of residual chlorine. Dechlorination is beneficial, especially because it reduces acute toxicity and even mutagenecity associated with chlorinated water. In addition, dehalogenation will prevent further formation of THMs in the offshore marine environment.

2. *Impact on the inland environment*

(a) If not disposed of properly, brine reject can pollute the same groundwater resources used as feed water for RO systems.

(b) Productivity of agricultural lands can deteriorate by the deposition of air-borne salts from dried brine used in the irrigation of halophytes.

(c) The environmental problems associated with thermal desalination such as residual chlorine, heavy metals and thermal pollution etc. are not usually transpired in BWRO.

(d) The facile and common practice of disposing of high salinity brine water, particularly from small (skid) RO units in municipal sewerage in some ESCWA member countries, will ultimately lead to the rise of TDS in domestic sewage and render the treated effluent inappropriate for reuse in agriculture. Diversion of reject brine to the sea through storm water collection systems is a valid option to be considered by the industry.

(e) Reject brine resulting from inland BWRO can be pumped into a lined and sealed pit or pond and left to evaporate. In most of the ESCWA member countries, the prevailing warm weather and excellent solar radiation, and the availability of land at reasonable prices, enable the use of evaporation ponds.

(f) The concentration of reject brine into solid salts using solar evaporation may cost $1.15 to $1.88 per 1,000 gallons of desalinated water using 1985 United States dollar values. The estimated cost of disposal of reject brine in an evaporation pond is 15% of the total desalination cost. The estimated cost for the disposal of reject brine by deep well injection ranges from $0.1 to $1.15 per 1,000 gallons of desalinated water at the 1985 United States dollar values.

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(g) Under certain conditions, discharge of brine concentrate resulting from BWRO into the sea might be one of the best and most cost-effective available alternatives. However, special considerations should be given to the siting of the point of discharge to avoid any detrimental impact on environmentally sensitive areas.

(h) Recovery of mineral resources from desalination reject brine is considered to be a very attractive option in the ESCWA region, depending on tecno-economic feasibility. The hot and dry weather; the level terrain and the low cost of available land in most of the ESCWA member countries in the region make the process very appealing.

(i) Significant attempts are currently under way by countries in the ESCWA region to introduce a variety of salt-tolerant and economically beneficial halophytes. The quality of brine reject generated from BWRO is considered by many as suitable to such endeavours. However, environmental considerations should be carefully assessed before implementation.

3. *Recommendations*

(a) Prior to the construction of large-scale desalination plant, a full-fledged environmental impact assessment study should be carried out to cover all the potential environmental implications associated with the construction, commissioning, operation and maintenance of the facility.

(b) Desalination industries in the ESCWA region should develop increased awareness and understanding of environmental issues related to the desalination process and the methods of mitigating the adverse effects.

(c) The desalination industry should develop its own internal environmental management capacities for self-monitoring, auditing and reporting to the regulatory agencies. The industry should also take a proactive role in defining, assessing and managing its environmental problems to assist the competent regulatory agencies in weighing all benefits and costs of desalination while formulating the regulatory standards.

(d) The need for a regional concerted and coordinated research programme focused on the identification, assessment, management and control of the environmental aspects associated with brine reject disposal in the ESCWA region is fundamental.

(e) Outfalls and intakes structures of desalination plants should be well designed and engineered to avoid contamination of feed waters by discharged brine rejects.

(f) The quality, quantity, transport, transformation and ultimate fate and effects of brine reject should be subject to constant surveillance by environment regulating agencies in ESCWA member States.

(g) Environmental regulating agencies should delineate the limits of the legally permitted mixing, dilution and recovery zones for each large-scale desalination plant.

(h) Additional efforts need to be invested on the use of BWRO brine reject in the irrigation of halophytes and the identification of their associated environmental effects.

(c) Open sea is generally less vulnerable than enclosed bays and sounds to many impacts of brine water disposal. This can be attributed to the large volume and free exchange of water. Open sea currents and circulation patterns have a considerable capacity to transport, disperse, and dilute brine water constituents.

(d) The presence of trace metals and free residual chlorine (bromine) in the discharged brine water should be given the highest priority and considered a matter of environmental concern. The discharge of trace levels of residual chlorine oxidants either in open or enclosed sea waters will be very detrimental to aquatic life in the offshore marine environment.

(e) It is safe to assume that the increase in salinity of the open sea water in the vicinity of large sea water desalination plants has been overstated, and should not give reason for concern, particularly when offshore hydrographic circulation patterns are considered in the design and construction of the desalination plants outfalls.

(f) Effusions during the commissioning, recommissioning and/or start-up of a desalination plant, following construction or periods of shutdown for regular maintenance procedures, causes more biological damage then effluent regularly discharged from the normally operating plants.

(g) In some offshore localities of the Gulf, the average salinity in summer can reach some 48 ppt, as compared with 37 ppt in winter. These natural cycles of higher salinity are assumed to furnish indigenous marine biota with higher resilience and adaptation to fluctuations in salinity.

(h) In open and well-mixed offshore marine environment, the environmental effects of brine reject disposal will only be noticeable to within less than 300 metres from the point of discharge.

(i) The impact of thermal pollution in semi-enclosed offshore areas might be more significant and could be manifested by changes in community structure such as types of dominating organisms and by changes in the characteristics of the individual species such as lower tolerance and/or adaptation.

(j) Except in the immediate vicinity of the brine water point of discharge, it is very unlikely that the concentrations of trihalomethanes are significant enough to pose any serious ecological threat.

(k) The low boiling point THMs discharged with the brine might reach the desalination plant intakes and recirculate within the system. THMs can evaporate with the steam, then co-distill and concentrate in the potable water condensate. The possible appearance of THMs in desalinated water can pose a serious public health threat to consumers.

(l) Most of the reported data indicate that the levels of heavy metals associated with brine water disposal in the ESCWA region and around the world are minimal and often below the detection limits of the standard analytical procedures. However, the potential persistence and accumulation of these metals in the offshore marine sediment and biota should never be overlooked.

(m) Although the primary productivity was slightly less than that in the feed sea water zone, brine water disposal has not, in principle, impeded marine primary productivity in the outfall mixing zone.

and their abilities to recover differ greatly, however, and site-specific allowed excursion frequencies may be established if adequate justification is provided.

(h) *Chromium (VI) and (III)*

Except possibly where a locally important species is very sensitive, salt water aquatic organisms and their uses should not be affected unacceptably if the four-day average concentration of chromium (VI) does not exceed 50 ppb more than once every three years on average, and if the one-hour average concentration does not exceed 1,100 ppb more than once every three years on the average. Data suggests that the acute toxicity of chromium (VI) is salinity dependent; therefore, the one-hour average concentration might be underprotective at low salinities.

No salt water criterion can be derived for chromium (III), but 10,300 ppb is the EC50 for eastern oyster embryos, whereas 50,400 ppb did not affect a polychaete worm in a life cycle test.

The recommended exceeded frequency of three years is the Environmental Protection Agency's best scientific judgement of the average amount of time it will take an unstressed system to recover from a pollution event in which exposure to chromium exceeds the criterion. A stressed system, for example, one in which several outfalls occur in a limited area, would be expected or would require more time for recovery. The resilience of ecosystems and their ability to recover differ greatly, however, and site-specific criterion may be established if adequate justification is provided.

5. *pH*

The chemistry of marine waters differs from that of fresh water because of the large concentration of salts present. In addition to the alkalinity based on the carbonate system, there is also alkalinity from other weak acid salts such as borate. Because of the buffering system present in sea water, the naturally occurring variability of pH is less than in fresh water. Normal pH values in sea water are 8.0 to 8.2 at the surface, decreasing to 7.7 to 7.8 with increasing depth. Benthic invertebrates are probably more sensitive than fish to changes in pH and that mature forms and the larvae of oysters are adversely affected at the extremes of the pH range of 6.5 to 9.0.

For open sea waters, where depth is substantially greater than the euphotic zone, the pH should not be changed more than 0.2 units outside the range of 6.5 to 8.5. For shallow, highly productive coastal and estuarine areas where naturally occurring variations approach the lethal limits for some species, changes in pH should be avoided, but in any case should not exceed the limits established for fresh water, i.e., pH of 6.5 to 9.0. As with fresh-water criteria, rapid fluctuations that are caused by brine reject discharge should be avoided.

time it will take an unstressed system to recover from a pollution event in which exposure to chlorine exceeds the criterion.

2. *Temperature*

In order to assure protection of the characteristic indigenous community of a water body segment from adverse thermal effects, it is necessary that:

(a) The maximum acceptable increase in the weekly average temperature resulting from artificial sources is 1° C during all seasons of the year, providing the summer maximums are not exceeded;

(b) Daily temperature cycles characteristic of the water body segment are not to be altered in either amplitude or frequency.

Summer thermal maximums, which define the upper thermal limits for the communities of the discharge area, should be established on a site-specific basis.

3. *Total dissolved solids*

Marine fish exhibit variance in their ability to tolerate salinity changes. However, fish-kills in Laguna Madre off the coast of Texas have occurred with salinities in the range of 75 to 100 ppt. In order to protect fish and other marine animals, it is recommended that no changes in hydrography or stream flow (brine reject stream flow) should be allowed that permanently change isohaline patterns in the estuary by more than 10% from natural variation.

4. *Heavy metals*

(a) *Zinc*

Except possibly where a locally important species is very sensitive, salt water aquatic organisms and their uses should not be affected unacceptably if the four-day average concentration of zinc does not exceed 86 ppb more than once every three years on average, and if the one-hour average concentration does not exceed 95 ppb more than once every three years on average.

Three years is the Environmental Protection Agency's best scientific judgement of the average amount of time aquatic ecosystems should be provided between excursions. The resilience of ecosystems and their abilities to recover differ greatly, however, and site-specific allowed excursion frequencies may be established if adequate justification is provided.

(b) *Nickel*

Except possibly where a locally important species is very sensitive, salt water aquatic organisms and their uses should not be affected unacceptably if the four-day average concentration of nickel does not exceed 8.3 ppb more than once every three years on average, and if the one-hour average concentration does not exceed 75 ppb more than once every three years on average.

Three years is the Environmental Protection Agency's best scientific judgement of the average amount of time aquatic ecosystems should be provided between excursions. The resilience of ecosystems and their abilities to recover differ greatly, however, and site-specific allowed excursion frequencies may be established if adequate justification is provided.

The distance of BWRO from the point of discharge on the seashore is a vital factor in the capital and operating costs of the desalination process.

In Jordan, discharge of brine reject into the already threatened ecosystem of the Dead Sea must be carefully investigated. However, it appears in principle that the discharge of BWRO brine water of less than 20,000 ppm in TDS might be a good environmental opportunity to ensure partial restoration of this water-starved sea.

4. *Discharge through pipelines to municipal sewers*

The facile and common practice of disposing of high salinity brine water, particularly from small (skid) BWRO units in municipal sewerage in some ESCWA member countries, will ultimately lead to the rise of TDS in domestic sewage. The expensive biological methods used in these countries for the treatment of domestic wastewater does not remove TDS and will make the treated effluent inappropriate for reuse in agriculture. In this context, it is not recommended to use the domestic sewage collection network in the ESCWA region for the disposal of reject brine. Diversion of reject brine to the sea through storm water collection systems is another option to be considered, subject to availability.

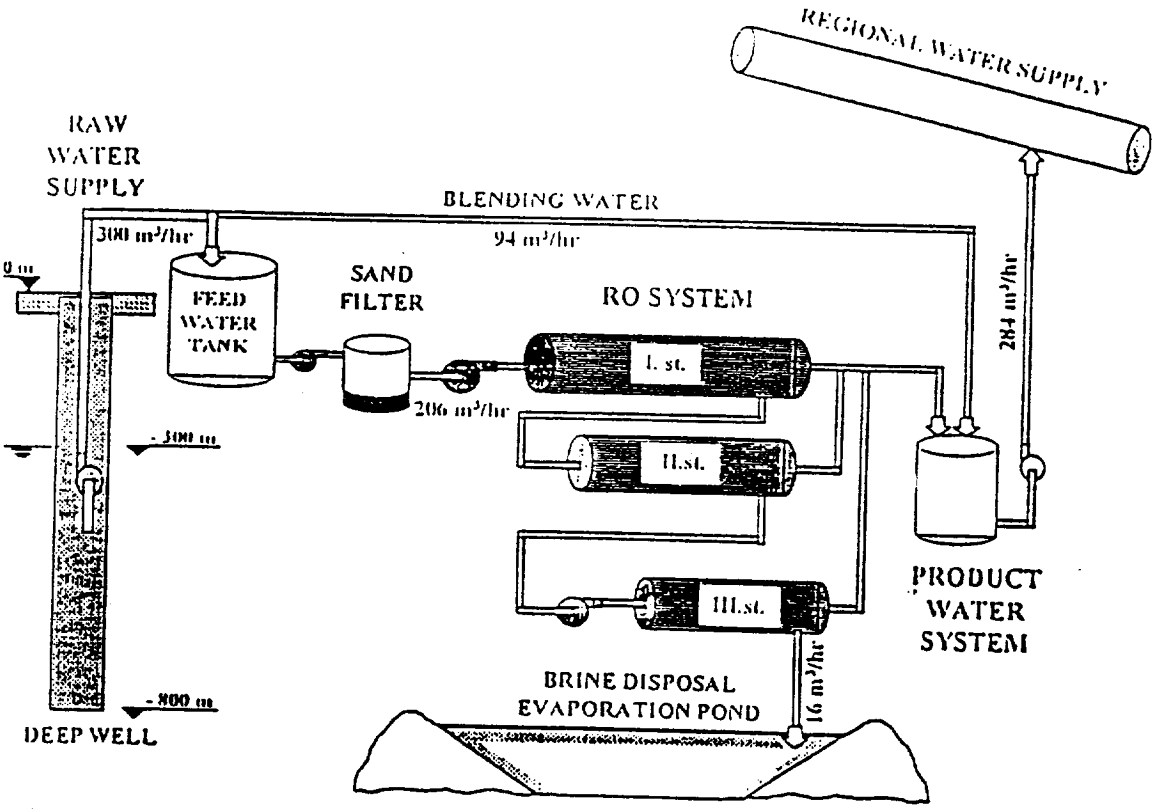
5. *Concentration into solid salts*

Recovery of mineral resources from desalination reject brine is considered a very attractive option in the ESCWA region, depending on the techno-economic feasibility. The hot weather, levelled terrain and the low land cost in most of the countries in the region make the process very appealing. Based on a preliminary economic assessment, Al-Mutaz and Wagialla (42) indicated that the extraction of magnesium from the desalination brine in the Gulf is economically viable. In addition, the process of extracting minerals from desalination brine is assumed to reduce the cost of fresh water production and minimize waste disposal. In a second techno-economic feasibility study, Al-Mutaz and Wagialla (43) were able to extract caustic soda at the Al-Jubail industrial area at a cost of $149/ton, based on 1982 prices. Mickley (44) emphasized that this option is generally expensive and that the techno-economic feasibility needs to be assessed on a site-specific basis.

6. *Irrigation of plants tolerant to high salinity (halophytes)*

Significant attempts are being made by countries in the ESCWA region to introduce a variety of salt -tolerant and economically beneficial plants. The quality of brine reject generated from BWRO is considered by many as suitable for such endeavours. If a large-scale programme is evolved for the cultivation of halophytes in the proximity of BWRO, the surrounding arid environment could be converted into green areas yielding immense economic returns. However, the environmental implications associated with these plans should not be overlooked. Special emphasis should be given to (a) the potential salinization of the irrigated lands, (b) percolation of high salinity water to the underground brackish feed water and (c) the potential transport of dry salt by wind to nearby productive lands. These potential environmental effects should be carefully assessed before implementing this option.

Figure II. 2. Simplified flow diagram of typical high recovery BWRO



Source: P. Gluckestern and M. Priel, "Optimized brackish water desalination plants with minimum impact on the environment", *Desalination*, vol. 108, pp. 19-26.

Note: BWRO = brackish water reverse osmosis.

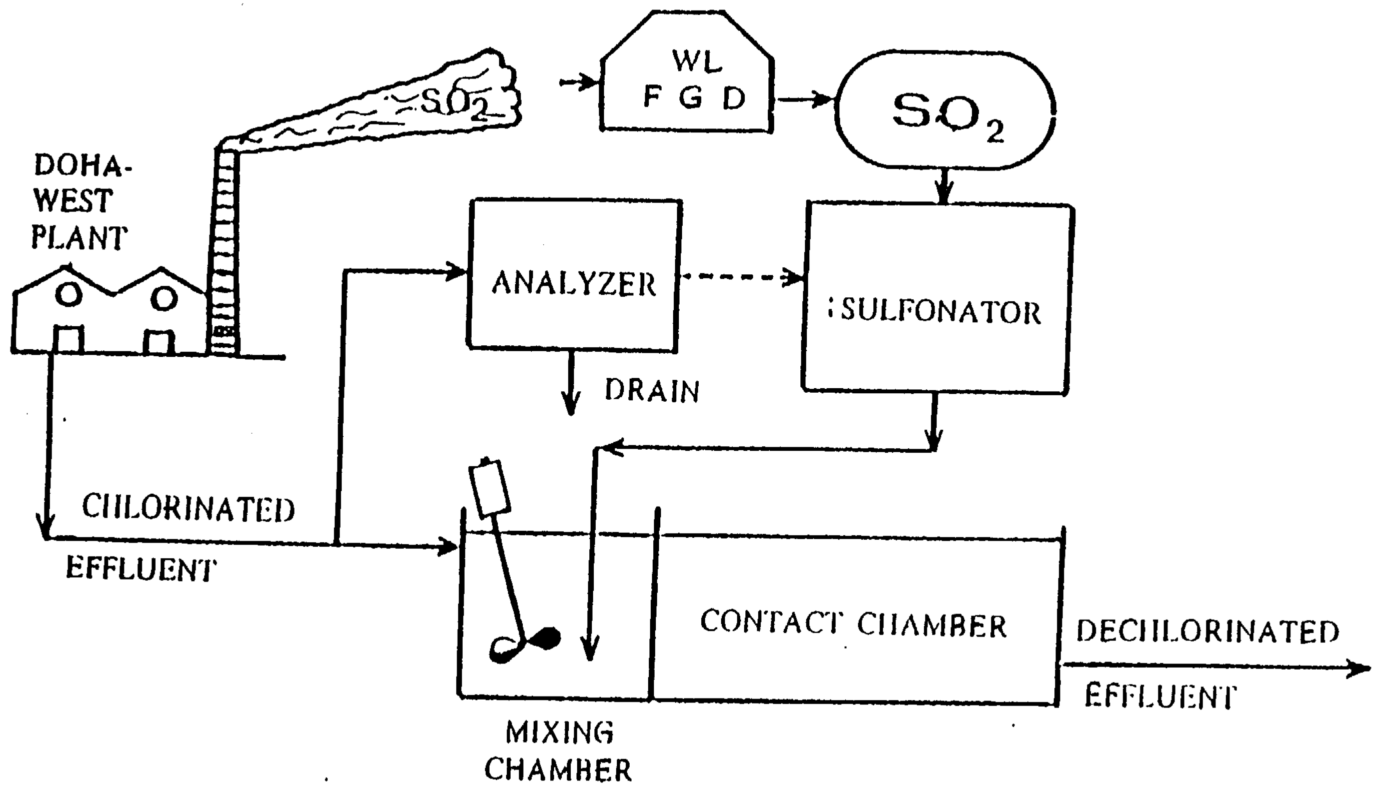
It should be recognized that, with all types of land disposal procedures, there will always be the potential risk of groundwater contamination. However, this risk becomes much lower when reject brine is concentrated into solid salts.

For the ESCWA member countries, the options available for the disposal of reject brine from BWRO are listed below.

1. *Pumping into specially designed lined evaporation ponds*

Reject brine resulting from inland BWRO can be pumped into a lined and sealed pit or pond and left to evaporate. In most of the ESCWA member countries, the prevailing dry and warm weather; excellent solar radiation and the availability of land at reasonable prices will ensure the economic and successful use of evaporation ponds. However, in order to reduce the land requirement and construction costs, it is essential to design a BWRO system with the maximum possible product recovery ratio, as illustrated in figure II.2. If the bottom of the pond is well sealed and evaporation is at least equal to the influent, such impoundment may receive and hold reject brine for many years. However, the seals may break down, leading to groundwater contamination, rain storms and/or flash floods that can cause overflows. According

Figure II.1. Simplified layout of proposed dehalogenation facility



Source: H.K. Khordagui, "Dehalogenation of cooling water using regenerated SO_2 emitted from thermal power plants in Kuwait," in Al Ta'awon Al Sina'e (Industrial Cooperation in the Gulf), issue No. 48, April 1992, pp. 3-14.

1. *Control of thermal pollution*

In order to minimize the environmental implications associated with thermal pollution, it is customary to select the plant site and design the brine disposal system, such that dissipation of thermal input takes place rapidly. The maximum allowable increase in the weekly average temperature beyond 300 metres seaward from the point of discharge is $1^{o}C$. In addition, daily temperature cycle should not change in frequency nor in amplitude (16). When designing for brine water outfalls, it is strongly recommended to avoid offshore enclosed areas and /or depressions.

In the event that environmental damage directly resulting from thermal discharges becomes evident, it will be necessary to pass the hot reject brine through a separate cooling pond or cooling tower before final disposal offshore. Past experience in the ESCWA member countries indicates that there is no real demand for these add-on brine water cooling systems.

2. *Control of residual chlorine (dechlorination)*

The strict ban on residual chlorine discharge in sea water and the adoption of near-zero discharge standards compelled the power and desalination industries in the West to search for solutions. According to Khordagui (11), the use of a chlorine substitute should be evaluated on the basis of three criteria before a judgment on its potential use is made. These criteria, although not all-inclusive, are effectiveness, environmental impact and cost. The available tested chemicals proposed as chlorine alternatives were found to be bromine, bromine chloride, ozone, ferrate, chlorine dioxide, hydrogen peroxide and potassium permanganate. The off-the-line mechanical control options to maintain boilers and condenser cleanliness in desalination plants are amertap balls, nylon brushes and/or metal scrapers. Other physical/chemical options available are application of toxic coatings to the inner walls of the desalination plants, rubber and copper-nickel sheeting and installation of electrode systems. Several optimization scenarios aimed at minimizing the use of chlorine were also developed (34). The most recent of these optimization systems is targeted chlorination (35, 36). Targeted chlorination seems promising, but the technique is costly, far from being well-established and does not address the macrofouling problem from the desalination plants to the condenser water boxes. The last and most promising available technique is dehalogination of the brine water. This technique has the advantage of producing an effluent with greatly reduced toxicity to the marine biota.

In general, the efforts to eliminate the environmental impacts of residual chlorine discharge were found to be basically grouped into the following three categories (11):

(a) Optimization shemes: this included targeted chlorination, chlorine minimization and off-line control;

(b) Chlorination alternatives: this included bromine, bromine chloride, ozone, chlorine dioxide, UV and ferrate;

(c) Chlorination/dechlorination: this included chlorine/activated carbon, chlorine/SO_2 and chlorine/holding ponds.

In a design of a conceptual approach to select the optimum control measure for residual chlorine discharge in Kuwait Bay using a scoring matrix, Khordagui indicated that out of the 12 available control alternatives, chlorination followed by dechlorination using regenerated SO_2 emitted from thermal power plants

8. *Collective impact of brine water disposal on the offshore marine biology*

Coastal marine environments include those water bodies lying over the inner portion of the continental shelf that are less enclosed and less saline than estuaries. The coastal waters generally lie within three miles of shore. The movement of water and the dispersion of pollutants are heavily influenced by tidal action and wind, as well as longshore currents, eddies and rip tides. When compared with estuaries, coastal sea waters tend to be moderately productive, because they receive fewer nutrients. However, submerged aquatic vegetation provides food and shelter for many organisms. As a result, coastal waters, particularly in the ESCWA region, tend to be ecologically important, and often contain important fishing grounds that can be affected by the discharge of brine concentrate. In the ESCWA region, a multitude of endangered birds and mammals migrate in the fall through the region and use its extended warm coastal waters, primarily to obtain food.

Data collected in 1997 by the Research and Development Center of the Saline Water Conversion Corporation (4) shed some light on the biological impact of brine concentrate discharge from desalination plants in Saudi Arabia, with special emphasis on chlorophyll production and abundance of zooplankton in the offshore marine environment.

According to the preliminary investigations carried out by the Saline Water Conversion Corporation (4) the outfall mixing zone in the Al-Jubail desalination plant exhibited the smallest decline in chlorophyll production throughout the duration of the investigation. SWCC (1997) reached the early conclusion that although the primary productivity was slightly less than that in the feed sea water zone, brine water disposal has not in principle impeded marine primary productivity in the outfall mixing zone.

In 1997, the Saline Water Conversion Corporation conducted an investigation on zooplankton biomass expressed as settled volume (ml/m^3) in the feed sea water zone as compared with the outfall mixing zone of the Al-Jubail desalination plant. In general, the preliminary investigations showed that zooplankton biomass in the outfall mixing zone is relatively lower in value than in the feed sea water zone, which is very similar to the levels observed in adjacent open sea areas. The feed seawater showed a diverse zooplankton assemblage with 43% of Copepoda, 19% bivalves, 9% protozoans and the rest made up of other less prevailing species.

TABLE II.3. PERCENTAGE COMPOSITION OF ZOOPLANKTON AT A DESALINATION PLANT IN SAUDI ARABIA

Plankton Group	% in feed water zone	% in outfall mixing zone
Protozoa	9.20	11.76
Polychaeta	1.66	0.94
Cladocera	7.35	7.59
Copepoda	43.15	57.33
Cirripedia	3.26	1.11
Pteropoda	4.25	5.27
Bivalvia	18.96	7.90
Appendicularia	3.81	1.82
Others	8.37	6.27

Source: Saline Water Conversion Corporation, "Impact of brine disposal from desalination plants in the Economic and Social Commission for Wes[tern] Asia Region", Jubail, Saudi Arabia, 1997.

TABLE II.2. DISTRIBUTION OF HEAVY METALS IN SEA WATERS ADJACENT TO THE AL-JUBAIL DESALINATION PLANT IN SAUDI ARABIA

Month/year	Feed sea water zone	Outfall mixing zone	Recovery zone
A. Copper in part per billion (ppb)			
January 1995	5.9	5.1	6.3
May 1995	2.1	1.5	1.8
October 1995	4.7	2.1	5.0
B. Arsenic (ppb)			
January 1995	2.6	5.1	3.7
May 1995	2.5	3.6	3.2
October 1995	4.6	3.5	3.1
C. Lead (ppb)			
January 1995	0.23	0.23	0.75
May 1995	0.5	0.17	0.68
October 1995	0.7	0.5	1.8
D. Nickel (ppb)			
January 1995	1.2	1.2	1.1
May 1995	0.45	0.4	0.4
October 1995	0.48	0.12	0.4
E. Iron (ppb)			
January 1995	8.5	8.4	7.5
May 1995	2.9	3.2	2.6
October 1995	3.3	3.5	5.6

Source: Saline Water Conversion Corporation, "Impact of brine disposal from desalination plants in the Economic and Social Commission for West[ern] Asia Region," Jubail, Saudi Arabia, 1997.

The resulting carbonate ions can react in either one of the following ways:

$$Ca^{2+} + CO_3^{2-} = CaCO^3 \quad .... (3) \quad \text{or}$$

$$CO_3^{2-} + H_2O = 2OH^- + CO_2 \quad .... (4)$$

Consequently, heating will cause the original bicarbonate content of the sea water to give an equivalent concentration of carbonate or hydroxyl ions. The respective concentration which can exist in solution is governed by the solubility product of $CaCO_3$ and $Mg(OH)_2$ respectively. At temperatures below 82° C, reaction (3) predominates and $CaCO_3$ deposition prevails. Above 82° C, hydroxyl ion formation is favoured, leading to $Mg(OH)_2$ precipitation.

In order to control calcium carbonate scaling, concentrated sulphuric acid (93%) is added to the feed water to remove the bicarbonate ions. The addition of sulphuric acid breaks down the bicarbonate alkalinity and prevents the calcium carbonate scales from forming according to the following reaction:

5. *Formation of trihalomethanes in brine water*

The formation of trihalomethanes (THMs) in brine water is a direct consequence of the chlorination process in which free chlorine reacts with the natural organics occurring in sea water and other organic pollutants acting as precursors to form THMs (28). Some of the volatile THMs species were found to be carcinogenic and mutagenic to humans (29).

In 1994 Shams El-Din and others reconfirmed that interaction of chloramines with bromide ions in seawater sets free elemental bromine which reacts with organic precursors in the sea water, forming brominated hydrocarbons that are known for their carcinogenic properties and may be harmful to seafood and possibly to human health (8).

According to Ali and Riley, out of 20 possible THMs only 4 were consistently detected in brine waters (10). Brominated species were dominating the formation distribution, with bromoform ($CHBr_3$) accounting for more than 90% of the total THMs followed by dibromochloromethane ($CHBr_2Cl$). The detected levels of total THMs in Kuwait ranged from 90 ppb in the immediate vicinity of the point of discharge to less than 1 ppb within a few kilometres seaward (10). Currently, there is growing concern within the scientific community about possible damage to the offshore marine ecology into which chlorinated brine is discharged. Except in the immediate vicinity of the brine water point of discharge, it is very unlikely that the concentrations of trihalomethanes are significant enough to pose any ecological threat. However, near the point of discharge the relatively high concentrations reported by Ali & Riley in 1986 (10) may have some effect. It has been known for some time that reproductive tissues and the immature stages of organisms, especially sperm, are sensitive to very low concentrations of THMs (30). In addition, 1982 Scott and others found that when adult oysters were exposed to seawater containing 25 ppb $CHBr_3$ the rate of respiration was increased and both the feeding rate and the size of the gonads were reduced. Rapid uptake of the compound occurred, but the depurination in clean water was complete within 96 hours. Although the feeding rate then returned to normal, damage to the gonads appears to be irreversible.

The problem is further complicated by the fact that low boiling point THMs can reach the desalination plant intakes and recirculate within the system. Once in the intakes, THMs will evaporate with the steam, then co-distil and concentrate in the potable water condensate. The possible appearance of THMs in desalinated water can pose a serious public health threat to consumers.

6. *Environmental impact of trace metals in discharged brine water*

In thermal desalination plants, it is plausible to find corrosion products in brine waters resulting from the effect of water flow, dissolved gases and treatment chemicals (acids) on the alloys utilized in the construction of desalination pipes and equipment. The corrosion products may include harmful heavy metals such as Nickel (Ni), Copper (Cu) and Molybdenum (Mo) and less toxic metals such as Iron (Fe) and Zinc (Zn). The amount of these metal ions is directly related to the redox potential, pH and the material in contact with water during the desalination process. According to Oldfield and Todd (32), brine containing corrosion products of desalination plants when discharged into the sea may become part of the liquid phase owing to their solubility or remain suspended in the liquid phase. Heavy particles may settle at the bottom in the sediments. The distribution pattern mainly depends upon the physico-chemical properties of the chemical species, weather conditions and geological factors.

3. *Environmental impact of thermal pollution from brine water*

The temperature of the brine water effluent resulting from thermal desalination processes is typically above the feed water temperature by 5° C to 8° C. However, Al-Tayaran and Madany (5) have reported 10° C to 15° C above the naturally occurring temperatures in the summer and winter seasons in Bahrain. The degree of damage to the biota present in the vicinity of the point of discharge is assumed to be a function of its type, the temperature levels (levels of exposure) and the duration of thermal inputs (duration of exposure).

In the life of marine organisms, temperature elevations from ambient values causes thermal stress that can result into an ecotoxicological effect such as disturbed enzyme activity, water balance and cellular chemistry (20). The buoyancy, locomotion and respiration of some marine organisms have been found by Tait to be disturbed as a result of temperature-induced changes in density, viscosity and solubility of gases in the receiving waters (20).

Manna (13) expressed concern about the temperature elevation and increased salinity of the brine water effluent discharged from duel power desalination plants in Saudi Arabia. It is important to note that the allowable increase in the weekly average temperature beyond 300 metres from the point of discharge is 1° C. The daily average temperature cycle should not change, in frequency or amplitude.

According to an ESCWA study (16), if the environment is open and well mixed, then the effects of effluents discharged will only be noticeable to within 300 metres from the discharge point. This finding was confirmed in the 1992 research conducted by Al-Tayaran and Madany (5), during which they discovered that at 160 metres seaward from the point of discharge from the Sitra power and desalination plant in Bahrain, no discernible pattern of temperature, salinity or DO differences were noticed.

The impact of thermal pollution in enclosed areas might be more significant and could be manifested by changes in community structure such as types of dominating organisms and by changes in the characteristics of the individual species such as lower tolerance and/or adaptation. Thermal pollution will lower the amount of DO, and increases bacterial and aquatic invertebrate activity, which in turn will diminish already lowered DO; it increases the growth rate of microscopic plants and fish and increases the sensitivity of aquatic life to toxic elements. The common practice in most large-scale and modern desalination plants in the ESCWA region is to ensure that these effects are minimized by selecting plant sites and engineering designs of discharge systems with a view to expediting the dissipation of their thermal inputs into the receiving offshore marine environment.

4. *Environmental impact of residual chlorine oxidants in brine water*

For well over half a century, chlorine has proved to be of immense benefit in controlling biofouling in power plants, and more recently in desalination plants, but its adverse toxic effects at trace levels have recently been discovered.

The chemistry of sea water is unique when chlorination is involved, owing to the presence of bromides in sea water. The bromide content of sea water ranges from 50 to 70 ppm, which will always be well in excess of any chlorine dose applied in the desalination operation. When chlorine mixes with sea water (pH=8.3), the chlorine reacts immediately with the bromide ions to form hypobromous acid (21) according to the following reaction:

$$HOCL + Br^- \text{ -------> } HOBr + Cl^- \quad ...... (1)$$

involve a somewhat higher ratio. For instance, multiple effects desalination requires 4.5 cu m of salty water to produce 1 cu m of desalinated water.

The collective environmental impact of the pollutants constituting the brine water discharged to the offshore marine environment might be expressed in one or more of the following forms:

(a) Physical impact: Resulting from the discharge of hot brine from thermal desalination plants;

(b) Chemical impact: Resulting from chemical agents remaining in the brine water and added within the process for the control of biofouling (chlorination), control of calcium carbonate scale formation (sulphuric acid, polyphosphates and recently polyelectrolytes), and antifoaming agents. In addition, sea water reverse osmosis necessitates an exhaustive pretreatment of the feed water to avoid accelerated fouling and scaling of the RO membranes. This pretreatment involves prechlorination, coagulation using coagulants (alum $Al_2(SO_4)_3.18H_2O$ or ferric chloride sulphate $F_eCl(SO_4)$) and coagulant aids (polyelectrolytes), sedimentation, clarification, sand filtration, and dechlorination using sodium bisulphate before conveyance to the RO membranes;

(c) Biological impact: Biological impact is the secondary effect of oxygen demand exerted by the natural and induced organics in the brine water. Relatively higher levels of biochemical oxygen demand (BOD) might be observed in the desalination plant effluents. The impact of BOD demand for dissolved oxygen (DO) associated with lower levels of DO in brine waters owing to higher salt content and temperature will ultimately reduce the level of DO in sea water adjacent to the brine water outfalls.

It is important to note that effusions during the commissioning, recommissioning and/or start-up of desalination plants following construction or periods of shut-down for regular maintenance procedures cause more biological damage than effluent regularly discharged from the normally operating plants.

1. *Environmental impact of increased salinity on open sea waters*

There has always been a misconception among some environmentalists that the concentrated salt content of the brine water disposed of by sea water desalination plants will inflict significant damage to the open offshore marine environment. Fortunately, this has not been the case in the ESCWA region for one or more of the following reasons:

1. The amount of sea water withdrawn for desalination is relatively minute when compared with the water mass of the open sea.

2. The amount and nature of salts discharged with the brine are identical to the salt content of the open sea.

3. The concentration factor increases by no more than two. In case the brine is discharged after blending with power production cooling waters for dilution, this ratio of two will significantly drop to near one.

4. In order to avoid recirculation of plant effluents to the intakes of the desalination plants, the outlets are specifically engineered to discharge in coastal areas where maximum circulation patterns and hydrographic currents can easily disperse and dilute the brine.

Despite the fact that dependency on desalinated water has substantially increased during the last 20 years in most countries of the region, the environmental implications associated with the discharge of reject brine water from desalination processes have not been given adequate considerations by concerned authorities.

The main objective of this part of this study is to fill this gap by identifying the environmental problems associated with brine water disposal (from sea water and brackish groundwater) in desalination plants in the ESCWA region. The environmental impact is assessed and measures are proposed for the alleviation or minimization of the impact.

B. PROPERTIES OF BRINE WATERS

As defined by Mandil in 1991 (3), the desalination device (plant) separates saline water into two streams: a low dissolved solid concentration stream (fresh water or desalinated water), and another stream containing the remaining dissolved solids (brine reject or blowdown). The general characteristics of the reject brine from some GCC desalination plants are provided in table II.1.

TABLE II.1. CHARACTERISTICS OF REJECT BRINE WATER FROM SOME DESALINATION PLANTS IN THE ESCWA REGION

Parameters	Abu-Fintas Doha/Qatar sea water	BWRO Ajman	BWRO Um Quwain	Qidfa I Fujairah sea water	Qidfa II Fujairah sea water
Temp. ^{o}C	40-44	30.6	32.4	32.2	29.1
pH	8.2	7.46	6.7	6.97	7.99
Cond. US/cm	---	16,490	11,325	77,000	79,600
Ca^{++} ppm	1300-1400	312	173	631	631
Mg^{++} ppm	7600-7700	413	282	2025	2096
Na^{+} ppm	---	2756	2315	17294	18293
$HCO3^{-}$ ppm	3900	561	570	159	149.5
$SO4^{--}$ ppm	3900	1500	2175	4200	4800
Cl^{-} ppm	29000	4572	2762	30487	31905
TDS in ppm	52,000	10,114	8,276	54,795	57,935
Tot. Hard. ppm	---	---	32	198	207
Free Cl2 ppm	Trace	---	0.01	---	---
SiO2 ppm	---	23.7	145	1.02	17.6
Langlier S.I.	---	0.61	0.33		
Cu in ppb	<20	---	---	---	---
Fe in ppb	<20	---	---	---	---
Ni in ppb	Trace	---	---	---	---
Antiscale ppm	0.8 - 1.0	---	---	---	---
Antifoam ppm	0.04 - 0.05	---	---	---	---

Note: --- = not reported.

To extract, separate and concentrate the salts in the reject brine solution, intensive thermal or electrical energy is required. During the process of desalination, the physical and chemical properties of the brine reject change significantly. The characteristics of the reject brine were found to be a direct function of the quality of

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* Issued as submitted.

(b) High priority should be given to water and wastewater management issues in the city of Jeddah.

(c) A comprehensive approach should be adopted towards the management of water issues in the city.

(d) A system of information should be established concerning legislation, emission standards, cleaner technology, waste minimization and other relevant issues influencing decisions on environmental management.

(e) A water conservation programme should be adopted and could be promoted through many tools, including raising public awareness and conducting educational campaigns, and adopting water efficiency-based pumping codes, and water pricing schemes that reflect the full cost of water production.

(f) Waste should be minimized through encouragement of changes in present household practices and through increased water recycling and the reuse of water.

(g) An enforcement and compliance system with clear delineated functions should be established.

(h) The Polluter Pays Principle, which reflects the price of environmental and health damage arising from pollution, should be adopted.

(i) Economic sanctions should be imposed to encourage water pollution control and user discharge.

(j) Water quality standards and the relevant pollution control and disposal guidelines should be reviewed and updated.

(k) Water pollution indicator methods should be applied to water issues in Jeddah.

(l) Sewage collection networks and treatment capacity should be expanded.

(m) The capacity of Jeddah's Industrial Waste Treatment Plant should be expanded, a chemical treatment facility should be added to it, and all industries should be connected to the Plant.

(n) All leaks in the water distribution, collection and disposal system should be inspected and repaired.

(o) The rising groundwater table should be controlled through water extraction or other solutions.

9. *Proposed recommendations for ESCWA input*

It is recommended that ESCWA should provide technical assistance for the following:

3. *Assessment of water quality and monitoring of wastewater*

This programme is part of the activities under the Jeddah city file. The programme studies and assesses water quality in Jeddah. Activities under this programme include making inventories and monitoring of municipal and industrial waste; investigating the ways and means of disposing of liquid waste (treated, partially treated and untreated waste), and monitoring of ambient water such as sea water and groundwater.

Under this programme, water samples have been gathered from the area of Khaleej Salman north of Jeddah up to the southern Corniche, and from Breaman to the Red Sea along an east-west axis. Collected samples were analysed for its chemical, physical, and biological parameters, along with other parametres. The Global Position System (GPS) was utilized in an attempt to allocate the sample points on the master plan of Jeddah. The number of samples covered 73 sampling points of sea water, groundwater, sewage water, and industrial effluents. In respect of the groundwater, there were around 12 boreholes covered.

Information gathered will be fed into the master plan of Jeddah by means of the Geographical Information System (GIS).

4. *Environmental permit and enforcement*

MEPA has not yet formulated a regular Environmental Permit to Discharge for the existing facilities. However, through an agreement with the Ministry of Industry and Electricity, MEPA reviews industrial applications for obtaining licences and issues a Certificate of No-Objection or recommends to the Ministry that Environmental Impact Assessments (EIAs) be prepared for those projects which may have a serious adverse environmental impact. EIAs in Saudi Arabia are mandatory for all development projects that could have an adverse effect on the environment.

Six agencies, including the Ministries of Agriculture, Industry and Electricity, Health, Municipality and Rural Affairs, MEPA and the Saudi Arabian Standards Organization (SASO), are involved in water quality and quantity issues, but none has the ultimate responsibility for enforcement of environmental regulations. Although MEPA is the central environmental agency, implementation of its environmental regulations, including the preparation of environmental impact assessments, is carried out by operational agencies in the different sectors.

5. *Routine inspections and reports*

MEPA standards include articles relating to MEPA powers to inspect factories, and formally request monitoring and other information. Therefore, MEPA has established a compliance or inspection programme within its Environmental Protection General Directorate to support implementation of the standards. Compliance efforts include contacts and discussion with various Ministries, governmental organizations, and the private sector concerning the environmental standards. MEPA is involved in the inspection of critical facilities and in preparing reports on the status of liquid discharges from these facilities. This is generally carried out as a reaction to complaints lodged by the public, a governor of a region (such as the Governor of Mecca), or government agencies (such as Civil Defence, Coast Guard).

In addition, MEPA is also involved in studying the environmental reports forwarded to it by other organizations such as Saudi Aramco and the Royal Commission for Jubail and Yanbu. These organizations

Major inputs of funding and technical expertise supported by a strong institutional structure with political commitment to improving conditions are needed to make any significant difference in water use and pollution in Gaza. There are many agencies working with and independently of the Government to improve various aspects of these problems. Master plans, evaluations and reviews have been written on environmental health, pollution and water resources. There is inevitably some overlap and duplication of efforts. The situation in Gaza is constantly changing, and new activities are starting up regularly. In order to assess current needs, a technical mission should be sent to Gaza to meet with government officials and other major donors to ensure that efforts are coordinated and assistance is provided in the areas of greatest need.

1. *Land use planning and development of national legislation*

Land use planning is a specific area of concern in Gaza, with so many competing demands on the land and water resources. Technical assistance is needed from both water and land use experts in developing land use guidelines and further, more detailed legislation. Advocacy to promote effective legislation through a regional conference at the highest levels could help to persuade government officials in Gaza and other areas and countries to act quickly in passing currently drafted legislation on water pollution control.

2. *Water quality surveillance and monitoring*

In order to assess properly the causes and effects of water pollution, a comprehensive water quality and surveillance programme is needed. This requires basic infrastructure with laboratories, equipment and expertise for water quality analysis. Until now, some agencies do double testing—sending samples overseas as well as testing in Gaza—in order to test the reliability of results. This is wasteful both in terms of time and money and not sustainable in the long run. Assistance is required in setting up surveillance programmes and providing the infrastructure and training to carry them out effectively.

3. *Community-based planning and public awareness*

Public awareness of water pollution and conservation issues is of great importance in Gaza where water resources are so limited, so polluted and funding for improvements is slow in coming. USAID (United States Agency for International Development) is currently developing through work in Tunisia a methodology for improving urban environmental health through community involvement in assessment, planning and implementation of small-scale projects. This methodology, termed "Community involvement in the management of environmental pollution," is a relatively new concept for the urban areas of the Middle East, but has great potential in an area such as Gaza where the need is so great and the water and sanitation issues are already assessed by the people as being of high priority (3, 4). In addition to providing specific improvements such as improved cesspit construction and household drainage, this approach could assist in promoting an "environmental ethic" which is now lacking in Gaza. It could also provide badly needed data on household attitudes towards water pollution issues and present household water use and disposal patterns.

4. *Industrial water use and pollution*

Industry in Gaza is limited, but pollution from this source may be significant. A comprehensive study on industrial water use, effluent and potential pollution and the impact on health would fill a specific gap in current information available on Gaza and provide a guide for future industrial development in the area.

financial management of wastewater reuse will presumably be covered by the current study on this subject, but is an area where assistance will be needed.

5. *Sewage treatment and disposal in areas without sewerage systems*

The upgrading of the Damascus sewage conveyance, treatment and disposal systems should greatly reduce pollution of water supplies. However, there are large areas, both within and outside of Damascus city, which will not be covered by this system and where there are still dangers to public health through direct contamination of surface and/or groundwater. The Strategy for the Environment, to be produced in 1997, will address these questions, and specific assistance will be required to plan and implement activities reducing water pollution in these areas. In these areas, some of the interventions may be simple and low-cost, such as improving pit linings, requiring tankers to dump in designated areas or at local treatment works, and improving household hygiene practices. A review of these areas could include specific case-studies in rural and peri-urban areas, including community-based studies and promotion of environmental awareness through mass media and other promotional activities.

6. *Pollution from agrochemicals*

Before developing a programme to encourage reduced use of agrochemicals, specific data are needed in order to quantify and point out the specific health hazards. High nitrate levels, for example, could be from domestic wastewater or agricultural pollution, and it is important to know the source of pollution in order to prioritize scarce resources in planning pollution control measures.

B. WATER POLLUTION CONTROL IN GAZA

The task facing administrators and planners in Gaza in addressing environmental problems is formidable. Major problems are similar to those in many Middle Eastern countries, but are more drastic in most cases owing to the continuing water pollution and rapidly depleting water resources. The pollution problems are a result of the following:

(a) Lack of basic infrastructure (sewage disposal, solid waste disposal) owing to limited funding;

(b) Lack of clear institutional structure;

(c) Lack of legislation and enforcement mechanisms to control water use or wastewater;

(d) Lack of comprehensive land use planning and/or integrated water resources management;

(e) Lack of a comprehensive water resources monitoring programme, providing sufficient data to make policy decisions, especially as regards industrial pollution and pollution of sea water;

(f) Lack of expertise in specific fields, particularly in industrial pollution and wastewater treatment and reuse;

(g) Lack of awareness at all levels of pollution-related issues and possible solutions.

E. Water Quality Standards of the Meteorology and Environmental Protection Administration

MEPA, as the central environmental regulatory agency, developed and promulgated its Environmental Protection Standards (No. 1401-01) in A.H. 1401 (1981). The Standards are being regularly updated and upgraded, the latest in the series being 1988-1989 (Document No.1409-01, A.H. 1409). These standards comprise air and water quality sections. The water quality standards were promulgated in order to minimize the volume of waste generated; reduce discharge of pollutants at source to a minimum; ensure maximum assimilation of pollutants; protect the quality of the ambient water bodies; and control the quality of wastewater before discharge to the central treatment facility.

1. *Receiving water guidelines*

These guidelines are applied at the edge of the mixing zone and beyond. The guidelines cover physiochemical pollutants as well as organic, inorganic and biological contaminants. These are interim guidelines until the relevant standards are developed for the receiving water bodies.

Each interim guideline refers to a 30-day average. The national receiving water guidelines stipulate that the maximum changes from the typical local baseline concentration at the edge of the mixing zone, resulting from the discharge of physiochemical, inorganic and/or organic pollutants, must not exceed 5% for the residual chlorine, total suspended solids (TSS), dissolved oxygen (DO), turbidity, chloride, chemical oxygen demand (COD), total organic carbon (TOC), total Kjeldahl nitrogen (TKN), chlorinated hydrocarbons, oil and grease, total cyanide, phenols, ammonia, total phosphate, arsenic, cadmium, total chromium, copper, lead, mercury, nickel, and zinc. Maximum changes of 0.1°C in ambient water temperature are permissible at the edge of the mixing zone as a result of wastewater discharge. For oil and grease discharge, the MEPA guidelines require that facilities using, transporting, or storing oil and petroleum hydrocarbons must adopt measures including the preparation, maintenance and update of plans covering spill prevention, control and clean-up. The discharge of foldable material is not tolerated. For biological pollutants, the MEPA guidelines stipulate that the total coliform levels at the edge of the mixing zone must not exceed the most probable number (MPN) of 70 per 100 ml.

2. *Performance standards for direct discharge*

These standards are applicable to a facility that intends to discharge waste directly into a receiving body of water. The purpose of these standards is to ensure that sources adapt the best practical technology in a way that pollution is controlled at its origin. The standards cover sanitary sewage, surface run-off, cooling water discharges, boiler water and air-conditioning blowdown, process water, and any other stream of industrial or municipal origin. Wastewater of different types must be isolated to the maximum extent possible. Dilution of streams to meet the standards is prohibited. Uncontaminated surface run-off and once-through cooling water may be discharged into receiving water without treatment as long as their thermal input does not exceed the stipulated guidelines for receiving water of 1°C. The national receiving water guidelines and performance standards for direct discharge were promulgated in order to protect primarily the Saudi Arabian coastal marine environment for industrial, commercial and recreational uses and to protect the aesthetic appearance of the waters and prevent excessive turbidity, eutrophication and odours.

3. *Pretreatment guidelines for discharge to central treatment facility*

These guidelines are aimed at providing a base for designing a facility for any Government, public or private organization interested in developing its own treatment facility. Accordingly, these guidelines are not binding as long as the quality of effluents from a treatment facility conforms to the MEPA performance standards for direct discharge.

C. POLICIES AND LEGISLATION GOVERNING WATER CONSERVATION AND PROTECTION

Understanding water technology helps to avoid many problems. This is because policies and legislation governing water conservation and protection in the Kingdom must be based on the philosophies of the best methods of water utilization and environment protection. Taking into consideration this concept, the following are some of the policies, laws and regulations on the development, utilization, conservation, protection and management of water resources in the Kingdom of Saudi Arabia.

(a) For the purpose of conserving water resources, Royal Decree No. M/34, dated A.H. 1400 (1980), concerning the conservation of water resources was issued. The Decree was endorsed by Resolution No. 140 H dated A.H. 1400 relating to the Water Conservation Ordinance which set out the rules for the conservation and regularization of water use.

(b) Well drilling is regulated by the Ministry of Agriculture and Water. No drilling is licensed unless it is approved beforehand by the Ministry, which stipulates the necessary conditions and specifications for execution, taking into account the hydrological situation at the proposed site.

(c) Royal Decrees issued have prohibited drilling at some sites, either because water quantity is insufficient or water recharge in the area does not compensate for the amount of water drawn.

(d) Sediment removal from certain wadis has been restricted by Royal Decree No. 114/M of A.H. 1407 (1987). These sediments are considered as water containers and should be reserved.

(e) Old wells or wells drilled in violation of established regulations were destroyed and a large number of wells throughout the country have been covered over.

(f) A network for monitoring undergroundwater has been established to check water levels and movements throughout the Kingdom.

(g) Royal Decree No. M/62 dated 20/12/1405 H approved Council of Ministers Resolution No. 225 dated A.H. 1405 (1985) pertaining to the Public Utilities Ordinance, which is concerned with the protection of wadis and water installations from dumping of trash and other forms of environmental abuse.

(h) Royal Decrees have been issued prohibiting the conveying of water to large complexes such as hospitals and schools unless they are equipped with automatic water shutters and other modern water-saving techniques.

(i) Organizations that own housing complexes have been instructed to use drainage water or treated wastewater for watering their lawns.

(j) Farmers are encouraged to apply modern irrigation techniques for efficient water use, ensuring optimum water conservation.

(k) Farmers are also directed to use treated wastewater for agricultural purposes.

(l) Several pricing categories have been established for penalizing subscribers in order to encourage all water users to conserve water.

2. *Management of water resources*

The Government implements its water policies and legislation through the following ministries, organizations and agencies:

(a) The Ministry of Agriculture and Water, which is responsible for planning and development of all water resources, and is a key organization in implementation of most agricultural and water-related policies and programmes such as irrigation and drainage support to small farmers. The Ministry is also in charge of licensing all activities concerning agriculture, fisheries, forestry and the exploration and use of water resources.

(b) The Al-Hassa Irrigation and Drainage Authority, which introduces modern technology, including the construction of aqueducts, for the irrigation of extensive areas of cultivated land in the Al-Hassa Oasis.

(c) Municipalities: in addition to providing drinking water, municipalities are also responsible for street cleaning and for regularly collecting and safely disposing of all forms of waste (sewage, garbage, rubbish). Reuse of treated effluents for irrigation of plant nurseries and public greenery is practised. Community sanitation control measures cover a wide range of activities.

(d) Ministry of Municipal and Rural Affairs: water and wastewater services are handled by the Ministry on a regular basis through six water and sewage boards staffed by the Ministry and chaired by a responsible Governor or Deputy.

(e) The Meteorology and Environmental Protection Administration: the main duties and functions of MEPA were grouped into the following categories: environmental surveys and pollution assessment, establishment of environmental standards and regulations (relating to air, water and land pollution, disposal of solid, liquid and gaseous waste, use and disposal of all chemical, pesticide and radio-active materials, and control of pollution of food and drinking water), recommendations on practical measures for emergency situations, keeping abreast of environmental developments on the international scene, and preparing and issuing climatological, environmental and meteorological analyses, forecasts and bulletins in real and non-real time format.

(f) The Royal Commission for Jubail and Yanbu: through a memorandum of understanding with MEPA, the Royal Commission was delegated to accomplish all environmental management functions. This requires regular self-monitoring of all pollution levels by individual enterprises and continuous monitoring of ambient air and water, noise levels and landfills by a specialized private sector firm contracted by the Commission.

(g) The Saudi Arabian Standards Organization (SASO) is the national organization on quality control. It prepares and publishes performance and product standards (such as on bottled water)and includes a stipulation that goods and commodities will not have an adverse effect on the environment or create a health hazard.

B. INSTITUTIONAL MANAGEMENT

The Kingdom of Saudi Arabia lies at the crossroads of three continents: Europe, Asia and Africa. It occupies about 80% (2.25 million square kilometres) of the Arabian Peninsula. The country is bounded by Jordan, Iraq, and Kuwait on the north, and by Yemen, Oman, the United Arab Emirates, and Qatar on the south and east. Saudi Arabia's Red Sea coast on the west stretches for 1,760 kilometres, and its eastern coast on the Gulf covers 570 kilometres. Along the Red Sea lies a narrow plain whose width varies from place to place. The central plain, which is characterized by extensive marshlands and lava field, is called the Tihama. The highest mountains are in the south-west, where peaks rise to 900 feet. Then they decline to 3,000 feet. To the north, the plain of Najd extends for nearly 900 miles. In the south is the Rub Alkali, the largest desert in the world.

The country has an arid climate with mean temperatures (from June to August) of between 23°C and 35°C temperatures and can exceed 48°C and may reach 0°C in the northern inland regions. Generally, the relative humidity during summer months is less than 25% over the inland areas, while in the coastal regions the mean ranges from 50% to 60%. During winter, the relative humidity rises to 50% in land areas and 60% to 70% in coastal regions. During certain periods, the relative humidity reaches 90% in the coastal regions. The mean annual rainfall is about 120 mm and may increase to 400 mm on some parts of the western and southern heights. Most of the precipitation falls in March and April. The population of Saudi Arabia in 1992 was estimated at 16.9 million, with a population density of 7 per 52 km. Approximately 78% of the population is concentrated in urban areas.

The economy of Saudi Arabia relies heavily on oil production, since 90% of earnings and government revenues comes from the export of crude oil. However, diversification into downstream products in the petroleum industries and into other manufactured and agricultural products is considered an important economic development strategy for the country. This strategy resulted in an average annual growth rate of 20% over the last 20 years in the non-oil sector. Furthermore, the number of manufacturers increased from 200 in 1970 to 2,476 in 1996. Nowadays, Saudi Arabia's economic structure depends on a modern industrial base and the country's infrastructure ranks among the best in the world.

1. *Environmental institution framework*

The Kingdom of Saudi Arabia is an Islamic Sovereign State. Its religion is Islam, its Constitution is based on the Holy Koran and the Prophet's Sunna. In this regard, justification for environmental management can be found in the teachings of Islam, which ordained that mankind should thrive and inhabit the earth. Accordingly, utilization of the natural and environmental resources of the Kingdom has been with the purpose of satisfying man's current requirements without endangering the abilities of future generations to meet their needs from the same resources. To this end, the Kingdom of Saudi Arabia in article 32 of its Basic Rules stated that the Government should endeavour to conserve, protect and develop the environment as well as to prevent pollution.

At the policy level, environmental issues are complex. Planning decisions which affect the environment have fundamental effects on the economy and on the public health of the Kingdom's citizens. Furthermore, owing to the considerable competition between different user groups, careful consideration must be given to development activities. Therefore, in order to ensure an equitable and effective environmental management programme, the Ministerial Committee for Environment was formed by Royal Decree, No. SB/5635 dated A.H. 1410 (1990). The Committee is chaired by the Second Deputy Premier and Minister of Defence and Aviation (figure 24). This Committee is the highest environmental authority in the Kingdom and has been designed to address both policy and sectoral issues.

4. *Flooding and storm drainage*

Flooding due to the intensive thunderstorms in the region is a concern that has implications for both human safety and economic costs incurred with the damage caused to private and public property and infrastructure. Flood and drainage problem areas limit development or increase the costs of development and service. There will be a trend to develop more housing and industrial activities in these areas, such as Wadi Fatima, as demands for land in the city increase.

There is a conflict between the natural drainage system through the municipal area and the pattern of urban development. As a result, considerable channelization has had to be carried out to direct flood waters from developed areas and the transportation corridors (see figure 23). There are interrelated problems with high groundwater and sewage disposal, particularly with the deep wells, holding tanks and septic fields. There are still areas that are regularly flooded in the developed areas of the city and in areas that could be developed if and when drainage projects are completed. Maintenance of the drainage system is expensive and requires continuous operations. There are some areas where development has occurred in a way so that additional drainage works cannot be provided. There are also developments that are occurring on flood prone areas. Filling in flood plains and developing them may restrict flood water flows and can cause problems in the upper watercourses. Alterations of natural drainage can also change freshwater and nutrient regimes in the marine, salt marsh and mangrove areas.

5. *Groundwater table*

The level of groundwater in many parts of Jeddah is rising rapidly. In some places it is less than a metre from the surface. However, the rising water table in the whole area of Jeddah was estimated at 0.5 metres per year (24). The trend towards rising high groundwater is increasing with the development of the city and the increased amounts of water used. About 100,000 cu m per day of sewage is presently dumped in the north-eastern part of Jeddah and is making its way into northern Jeddah with no means of escape to the sea. Nevertheless, based on a groundwater budget calculated from 1992 data, nearly 60% of the contribution to groundwater originates from the land disposal of sewage (23). The soil conditions in the region are such that drainage is not good. As rains occur and drain through these areas, there is no extra capacity for the ground to absorb the run-off.

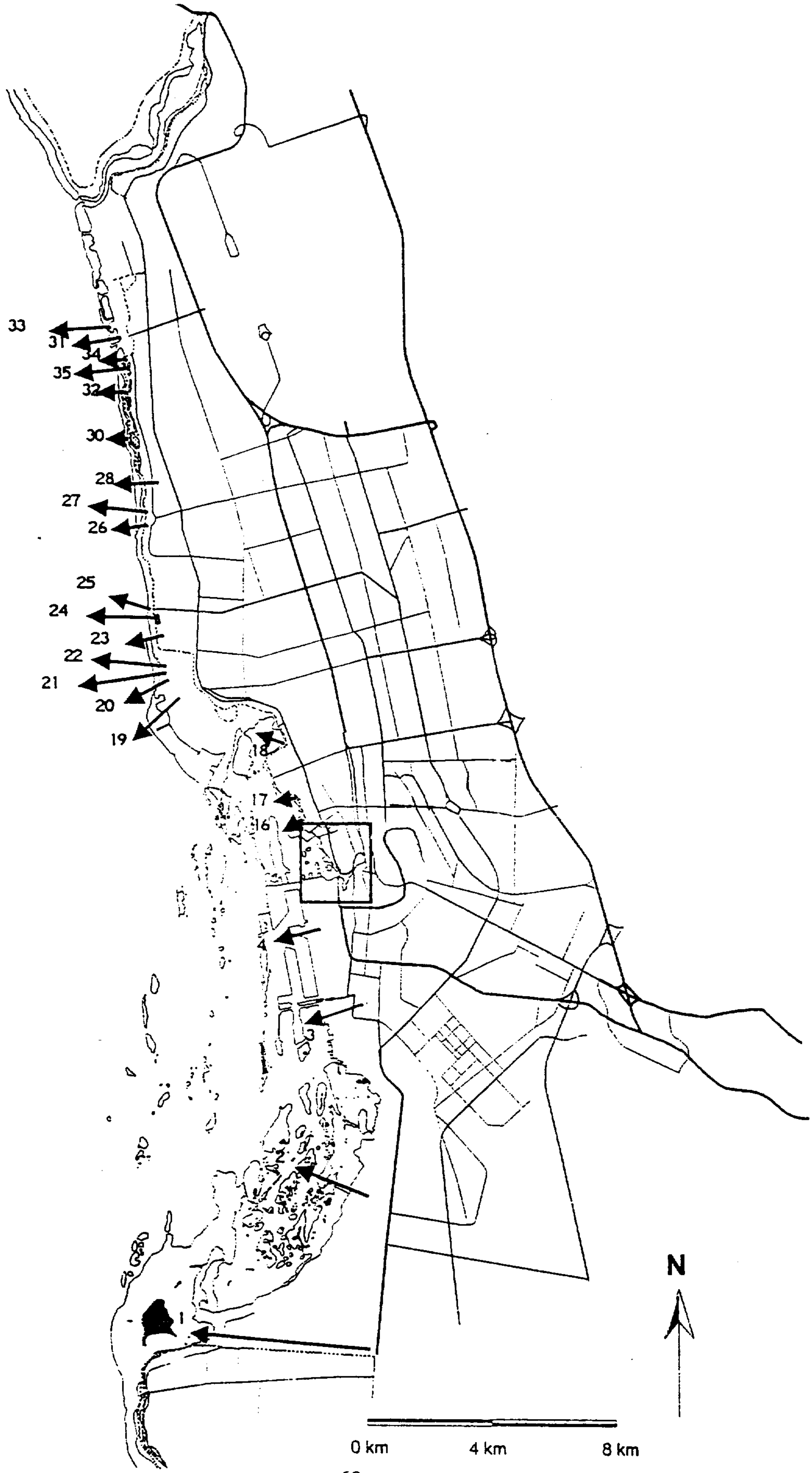
The impact of rising groundwater includes: damage to cement owing to the chemical content of the water; damage to drainage and transportation infrastructure; interference with sewerage infrastructure; and major hazards to people and property. It increases the construction and maintenance costs of all development. It also reduces the effectiveness of on-site sewage treatment and can cause health problems if sewage enters the water.

There have been concerns raised about the quality of the groundwater that might be drained into the sea. The salinity is very high (twice that of sea water) as is the hardness. This was initially thought to be a problem if the discharge of groundwater was to occur near the intakes for the desalinization plant.

With increased development in areas requiring sewage pumping (and thus increased dumping of sewage), cesspools, increased irrigation, and with the natural conditions of intense rainfall the problems relating to a high groundwater table will increase.

University studies on groundwater problems sponsored by the Water Sewerage Authority are continuing. These studies have indicated that one remedy to prevent damage from rising groundwater levels

Figure 22. Sewage and drainage discharges to the Red Sea



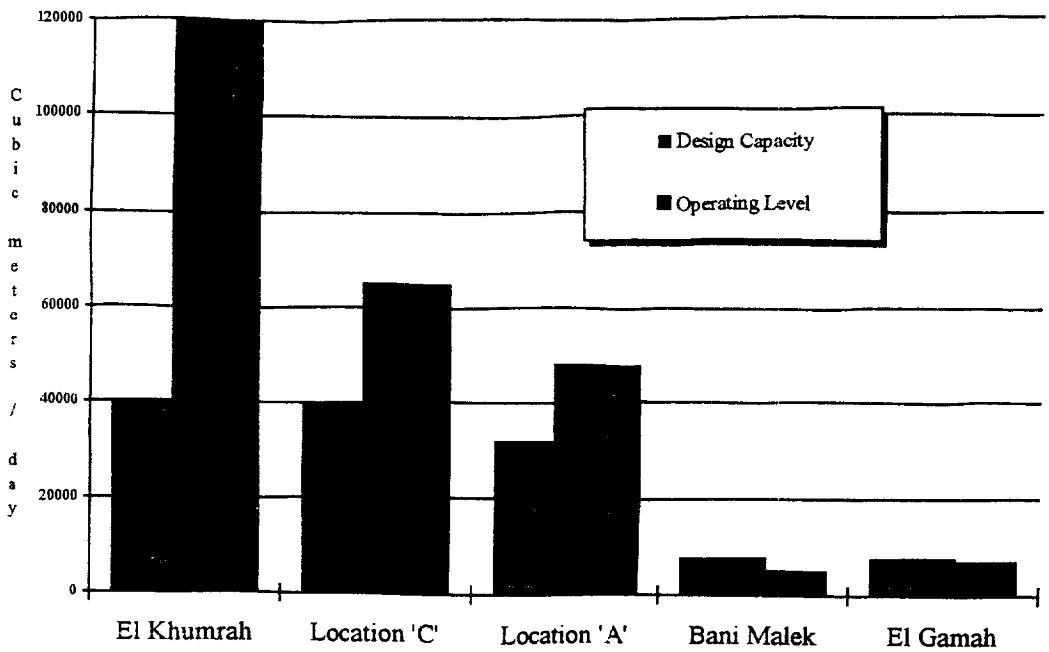
the area of north Jeddah believed to be the result of this supply of water, and the groundwater has been contaminated owing to these disposal practices.

These conditions tend to increase with population growth. In addition, the costs of remedial construction and maintenance will rise. With increases in the level of groundwater, there will be salinization of the water affecting vegetation. The rise in groundwater will reduce the effectiveness of any on-site septic and leaching facilities. As groundwater continues to rise, there is a greater potential for the problem to spread to the central areas of Jeddah.

There are numerous industries operating outside the limits of the industrial city. Their wastes are either disposed of through the municipal sewage system or into the sea or on land (the collection lake or in the desert). Figure 21 identifies the sites that are discharging treated or untreated sewage into the sea. Action is being taken to notify the responsible sources to remedy the problem.

The lack of an adequate sewage collection system and sewage treatment infrastructure for the disposal of untreated (and semi-treated) sewage into the coastal water along the Red Sea (and for other means of disposal) is creating severe problems in Jeddah, including health, ecological, and aesthetic problems. For instance, the operation of desalinization plants requires high quality sea water. Disposal of materials in the vicinity of the intakes can negatively affect the process through potential infiltration of wastewaters into the water supply system and cisterns. Another problem originates from the issue of wastewater collection and treatment and disposal, which is of growing significance, given the rising water table in Jeddah.

Figure 20. Comparison of design capacity and operating level of sewage treatment plants*



* The operating level of El-Kumrah varies considerably. The 120,000 cu. metres/day is a maximum that is frequently reached.

a 1995 estimate of approximately 130 mcm of treated sewage generated annually. This is almost three times the rated capacity of Jeddah's sewage treatment plants. However, sewage generation is expected to rise over 302,000,000 cu m by the year 2015 (23).

There are problems in developing new sewage treatment facilities in the areas that need them. In north Jeddah, even if there was a treatment plant in place, the disposal of treated material to the sea would be hindered by the intensity of shoreline development. Landowners in the area would not like to see treated sewage disposed of next to their residential or commercial developments.

Figure 19. Arbaeen lagoon set-up

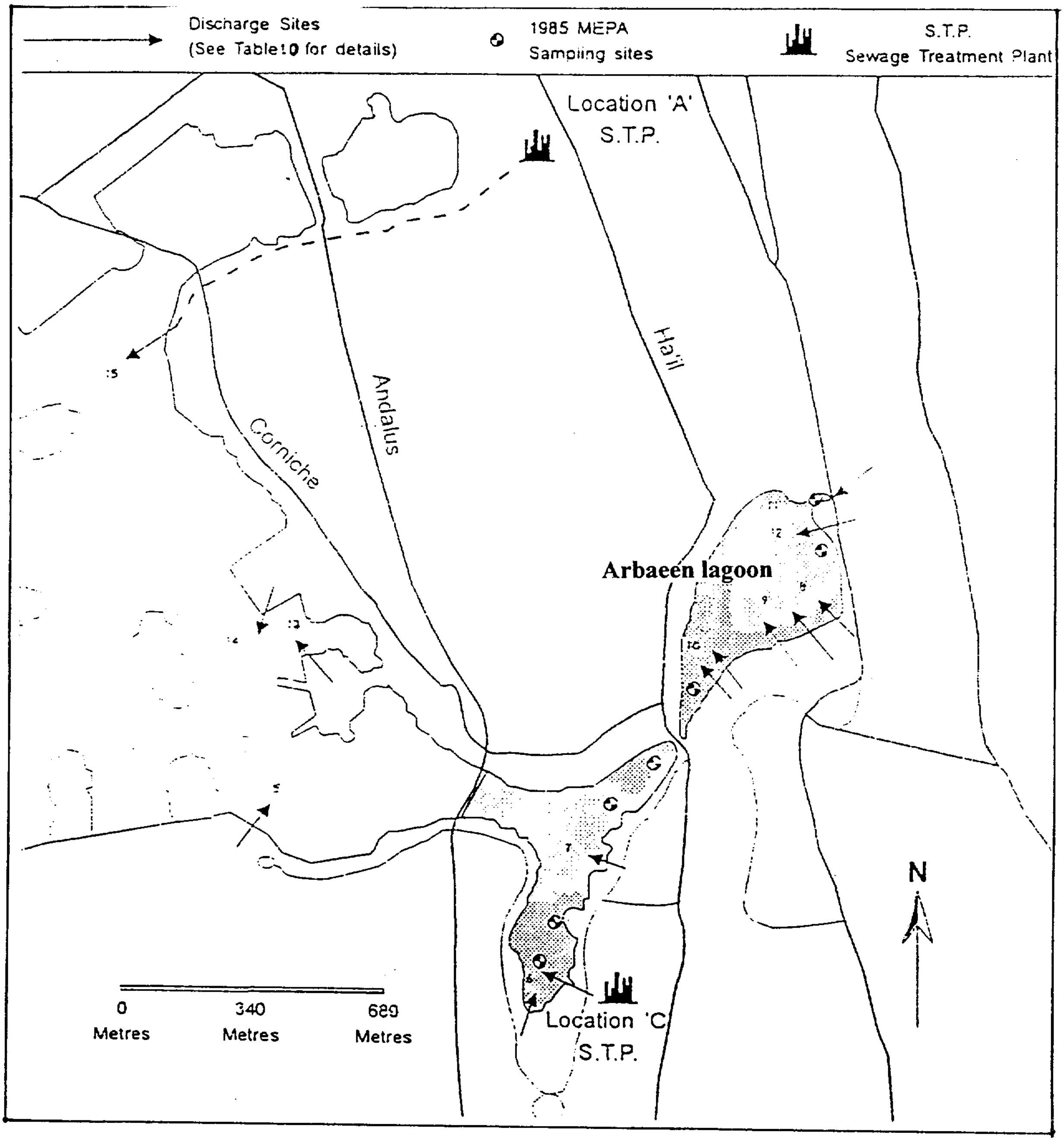


TABLE 14. EXPECTED WATER CONSUMPTION FOR THE COMING 30 YEARS

Year	Population (in thousands)	Personal consumption (LPD)	Total by Ministry x 1,000 LPD	Total by consultant x 1,000 LPD
1995	2135	364	777	850
2000	2356	402	947	1100
2005	2601	443	1152	1300
2010	2871	490	1407	1520
2015	3170	541	1715	1730
2020	3500	598	2093	1970
2025	3864	661	2550	2200

Source: Volumes are the mean averages of daily consumption as estimated by the author, based on a population growth rate of 2% and an increased rate of consumption per person per day of 2%.

Note: LPD = litres of water per day.

Figure 18. Comparison of levels of water consumption for Jeddah and Riyadh

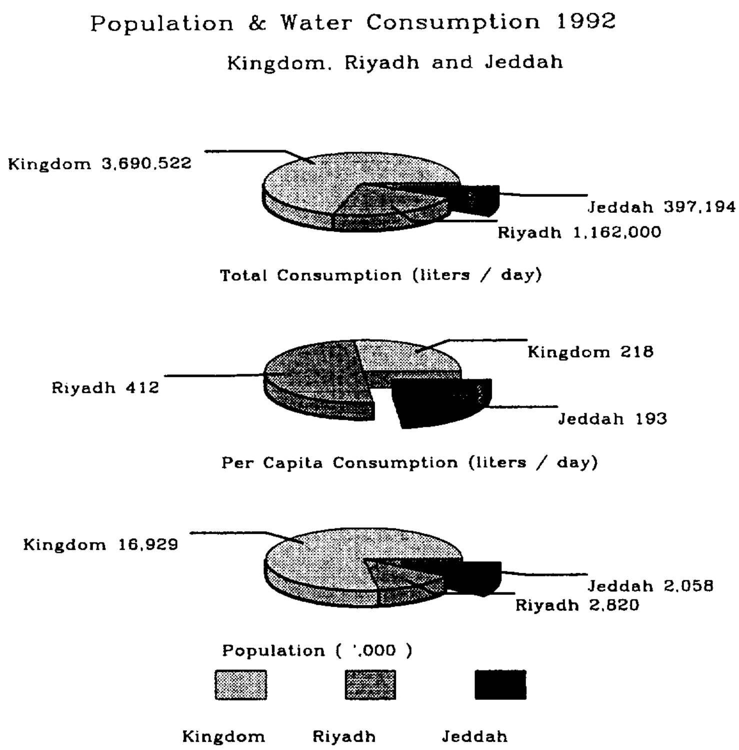


TABLE 12. ESTIMATED AND PROJECTED WATER CONSUMPTION IN JEDDAH

Year	Population	Water demand	Per capita consumption
1975	444 000	35.4	216
1980	585 000	65.3	304
1985	907 000	109	329
1990	1 360 000	165	333
1995	1 935 000	239	339
2000	2 587 000	332	352
2010	-	6	-

Source: O.S. Abu-Rizaiza, Study of Groundwater in North-South Jeddah, Final Report, Water and Sewerage Department, Western Region, Jeddah, Saudi Arabia, 1990.

Note: A hyphen (-) means data are not available.

Based on the 1974 survey data, the Swedish company VBB in 1975 estimated the per capita water demand for the years 1970, 1980 and 1990 at 200, 355 and 355 litres respectively. The estimate took into consideration daily per capita consumption for a variety of uses, including landscaping (which was estimated to be 25 litres), industrial uses (15 litres), recreation (10 litres), and air-conditioning (10 litres). Household consumption was estimated by VBB in 1975 at 200, 240, 260 and 280 litres per person per day for the years 1970, 1980, 1985 and 1990 respectively. Projected estimates for different functions are shown in table 13.

As can be seen in figure 18, the consumption of water per capita in Jeddah for the year 1992 was less than in Riyadh (25). It might be expected that, with further diversification of industry in the Jeddah area, increases in per capita consumption may become closer to the consumption levels in Riyadh. Actual population growth will also increase the total consumption of water. This growth will result in increased production needs and may increase the impact on the environment. However, some initial work was done in 1995 to predict water consumption for the coming 30 years in Jeddah. The work was carried out by a consultant engaged by the Ministry of Agriculture and Water, Western Region Projects. The result of this work is shown in table 14.

The per capita water demand in Jeddah was estimated at about 80 cu m per person annually in 1995 (23). Current production capacity is fully used to meet present demands. The reason for this massive water use originates from the rising per capita consumption. However, a large portion of observed water demand may reflect a high level of water loss through leaks in the water distribution network (estimated to be 40% of the reported supply, as reported in the *Arab News* [Jeddah], 5 April 1996).

In the absence of water conservation methods, income and population growth are expected to lead to an increase in water demand of 800 mcm annually in less than 20 years, by the year 2015 (23).

Figure 16. Available annual water resources for Jeddah, 1975-1995

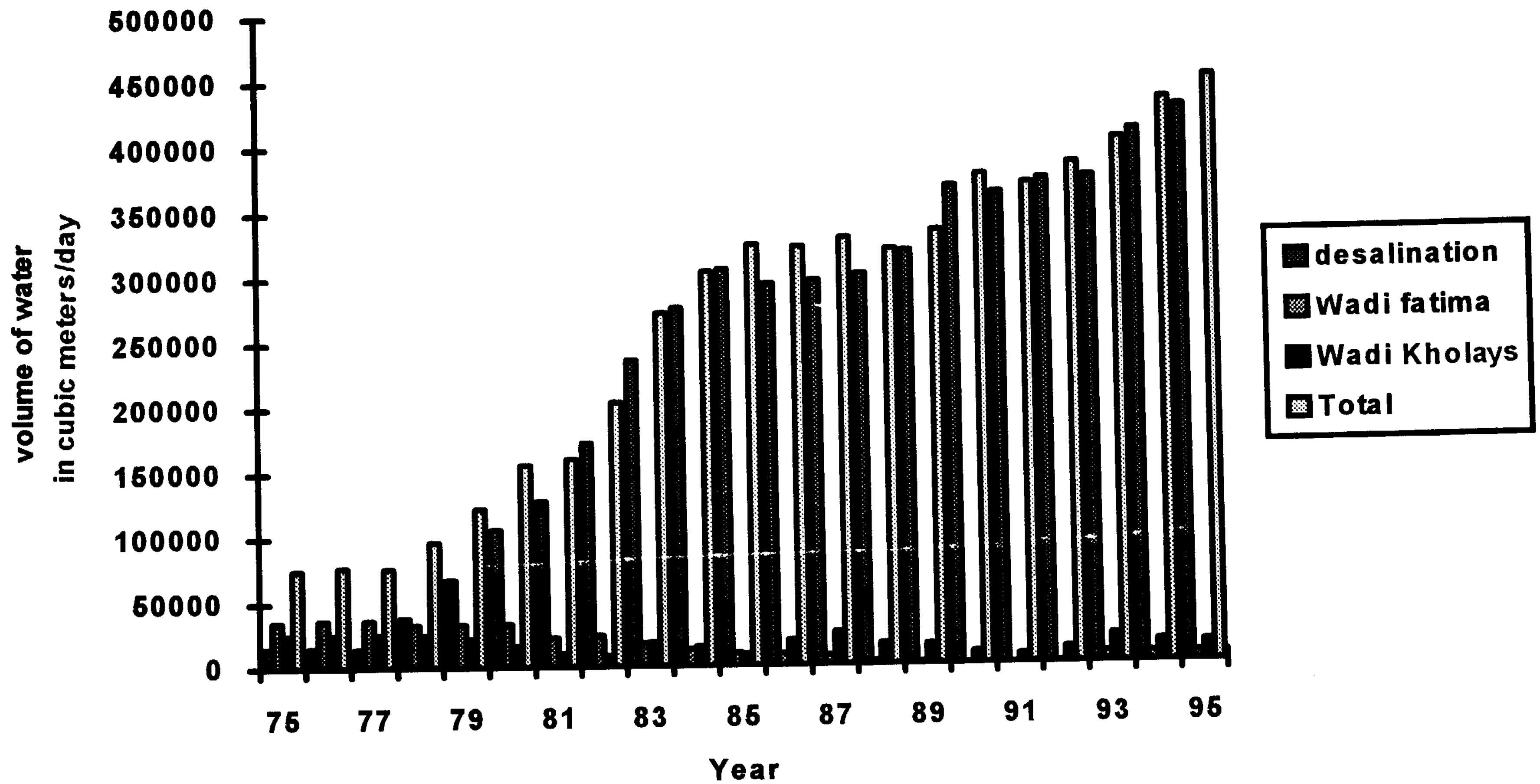


TABLE 11. ANNUAL AVAILABLE WATER RESOURCES FOR THE CITY OF JEDDAH, 1975-1995

Year	Desalination production cu m/day	Wadi Fatima production cu m/day (groundwater)	Wadi Khulays production cu m/day (groundwater)	Total
1975	15000	35000	25000	75000
1976	15389	36569	25365	77323
1977	14407	36569	25163	76138
1978	38475	33152	24954	96581
1979	67574	32780	21855	122209
1980	106324	33467	16278	156069
1981	127935	22466	10118	160519
1982	172669	24063	8186	203918
1983	236272	17952	18183	272407
1984	276195	13037	14847	304079
1985	305879	9643	8952	324474
1986	294645	8660	19246	322551
1987	296815	7000	25503	329318
1988	301459	2570	15971	320000
1989	318750	1501	15012	334363
1990	368000	85	8774	376859
1991	363000	0	6698	369698
1992	373200	590	11522	385312
1993	374600	7559	21311	403470
1994	410100	7161	16052	433313
1995	427500	7155	15366	450021

Source: Saudi Arabian Ministry of Agriculture and Water, Western Region Water Projects.

3. *Treated wastewater*

With the progress of science and technology, the concept of wastewater reuse for different purposes was developed especially for the irrigation of non-cash crops, landscape irrigation, and industrial cooling. The objective of the reuse is what defines the required treatment level.

The current wastewater collection system (1,500 km) covers only about one third of the currently developed area of Jeddah (25). There are a total of eight sewage treatment plants. This number does not include the Airport plant and other small private plants, which have a combined capacity of 176,000 cu m per day and are currently operating at 141% of their designed capacity of 43.8 mcm per year (23).

C. WATER CONSUMPTION AND UTILIZATION

In 1974, a field survey was undertaken by the Development Analysis Association on behalf of the Saline Water Conversion Corporation to estimate daily water consumption in the different districts of Jeddah. For survey purposes, the city was divided into 12 districts. A total of 8,532 residents in apartments and traditional houses, and 3,532 residents of villas were questioned. The annual water consumption was

B. WATER RESOURCES AND UTILIZATION IN JEDDAH

1. *Groundwater*

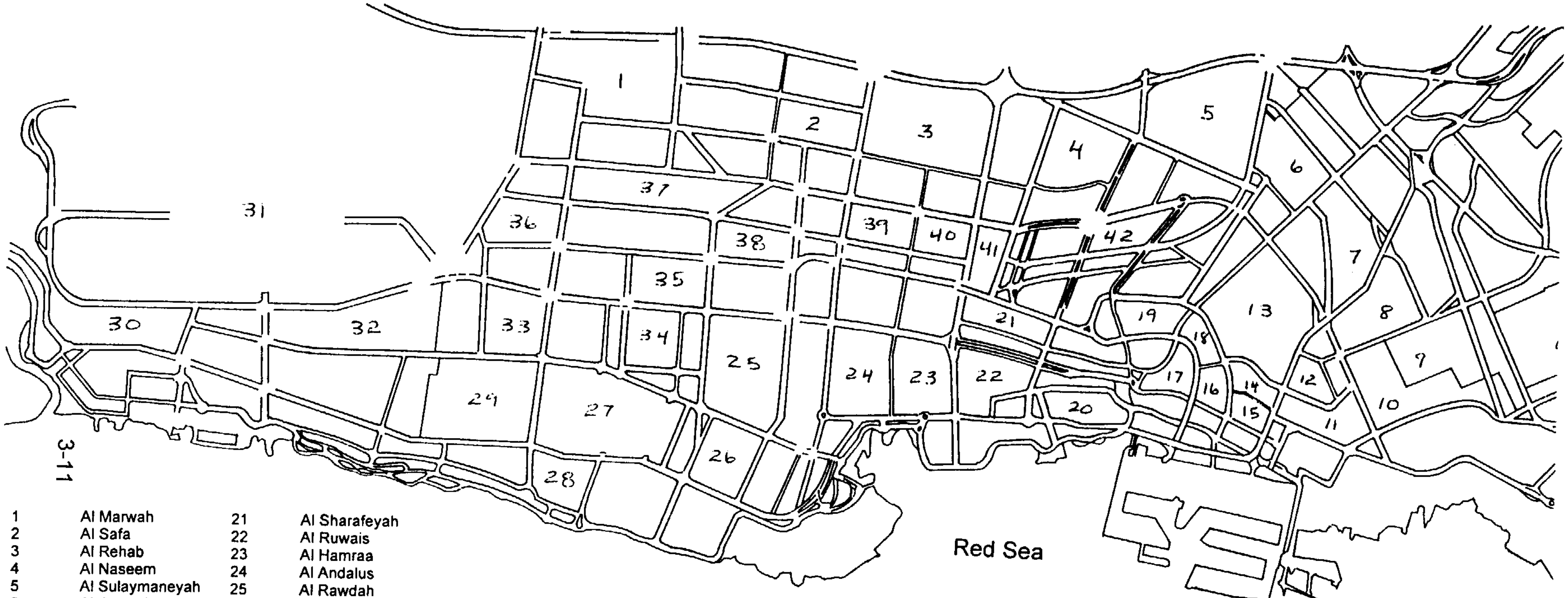
Water and water supply have always posed a problem for the city of Jeddah. As early as the sixth century, the city's rulers were obliged to dig 300 wells and cisterns to meet the city's demands (22). Al-Hamadani in the tenth century reported that Jeddah was parched and shriveled as a result of a drought (22). Ibn Battuta in 1330 described Jeddah's water system and reported that the year (1330) was one of little rain, so the water was brought to Jeddah from the distance of a day's journey. To overcome the water supply problems, between 1676 and 1683, the Grand Vizier Kara Mustafa Pasha funded construction of a water duct which carried water from wells located east of the city.

The Turks in the period 1900-1910 constructed a water distribution system consisting of two twin 12.5 cm in diameter terracotta pipes and a few kilometres of cut and covered tunnel to tap the Ain Wazira well located 10 kilometres east of the city. In addition, there were two wells within the boundary of the city. Rainwater was gathered at small trenches out of the city, but the quality of water was not acceptable for drinking water. Therefore, the first small-capacity boiler (*kindasah*) was installed in 1909. In 1926 King Abdulaziz had two water condensers established to produce enough drinking water for the city. Consequently, additional water was supplied to the city in 1926 and 1928 through two sea water condensing machines with a total capacity of 114 and 135 cu m per day respectively (21). The amount of water available from the Al Wazira well increased to about 216 cu m per day in 1932 through repair and improvement of the water conveyance system, and through installation of a windmill and auxiliary diesel pumping engine (21).

Ever since the Kingdom of Saudi Arabia was consolidated in 1932, Jeddah began to change its image, politically, economically, and architecturally. This led to an increase in water demand and the urgent need to search for other sources of water. In response, the Saudi Arabian local authorities, in cooperation with Aramco engineers and a United States agricultural mission, tapped water from the spring in Wadi Fatima near Abu Sheib. A pipeline 30.5 cm in diameter conveyed the water to a reservoir on the outskirts of the city with a capacity of 3,800 cu m. In 1954 a second pipeline, 61 cm in diameter, was installed to provide additional water from Wadi Fatima. From 1947 to 1955, the rate of water supply to the city was 9,300 cu m per day (21). This water came from 2 springs and 11 wells in Wadi Fatima, through large-diameter pressured lines. However, part of this water was also tapped to a few villages located along the lines. In 1975, the amount of water taken from Wadi Fatima had increased to 35,000 cu m per day (see table 10). Nevertheless, the unprecedented population growth led to a further shortage of water and more demand for other water resources. As a result of this, efforts began to focus on a second groundwater source in the alluvial aquifer of Wadi Khulays, which is located 110 kilometres north of Jeddah. Wells were dug there and water was tapped to provide the city with additional water. Daily water production from both Wadi Fatima and Wadi Khulays reached 60,000 cu m and 22,521 cu m in 1975 and 1995 respectively. The water supply network from both wadis is sketched in figure 15.

In the 1940s, 90% of Jeddah's water was supplied from wells or brought in by trucks from surrounding rural areas. The water distribution network within the city in the early 1940s consisted of a few pipe connections. At the same time, water was mainly delivered by two-wheeled donkey carts carrying 50-60 gallon oil drums filled with water, or by water vendors who supplied five-gallon gasoline tins to houses. However, history shows that the water supply of Jeddah has undergone many changes during the past 50 years. From 1970 onwards the city has depended largely on water desalinization plants.

Figure 13. Current urban growth in Jeddah



3-11

1	Al Marwah	21	Al Sharafeyah
2	Al Safa	22	Al Ruwais
3	Al Rehab	23	Al Hamraa
4	Al Naseem	24	Al Andalus
5	Al Sulaymaneyah	25	Al Rawdah
6	Al Jameah	26	Al Khaledeyah
7	Madain Al Fahd	27	Al Zahraa
8	Al Waureyah	28	Al Shatea
9	Industrial Estates	29	Al Nahdah
10	Al Mahjar	30	North Obhur
11	Petromin	31	King Abdulaziz International Airport
12	Ghulay	32	Al Mohammedeyah
13	Al Nuzlah	33	Al Naeem
14	Al Usryat	34	Al Salamah
15	Al Imaa Issail	35	Al Bawadi
16	Al Hindaweyah	36	Al Nuzhah
17	Al Balad	37	Al Habwah
18	Al Sabil	38	Al Faysaleyah
19	Al Kandarah	39	Al Azezeyah
20	Al Baghdadiyah	40	Al Mushrefah
		41	Bani Malik
		42	Old Airport

Figure (3.4) Jeddah Current Urban Growth

TABLE 10. POPULATION DISTRIBUTION OF JEDDAH: PAST, CURRENT AND PREDICTED FUTURE

Municipality Name	Population 1980	1985	1990	Population in 1995 Arithmetic	Geometric	Average	Predicted Population in 2000 Arithmic	Geometric	Average
Al Azziziyah	34000	105139	175700	159870	399405	294637	200261	778464	489362
Al Balad	241306	271804	305880	312337	344382	328359	317072	387664	352368
Al Jamea	173121	175135	198000	200488	211749	206118	202312	232834	217573
Aljanoob	13629	24960	39700	42307	67757	55032	44219	111637	77928
Almattar	54000	101485	149000	158500	247504	203002	165467	386520	275993
Alshrafiah	132296	133102	134840	135094	136130	135612	135280	137716	136498
Alshatea	19100	38200	54470	58007	91985	74946	60601	142739	101670
Jeddah	53000	61559	67100	68510	75500	72005	69544	83613	67578
Qasur	195548	165368	155300	151276	138398	144837	148325	126610	137468
Total	916000	7076662	1279990	1316389	1712810	1495559	1343081	2387797	1865438

Source: M.J. Abdulrazzak and A.V. Sorman, Domestic Water Conservation Potential: New Resources for the Major Cities of the Western Region, Final Report 1416, King Abdulaziz University, Faculty of Meteorology, Environment and Arid Land Agriculture, Department of Hydrology and Water Resources Management, 1996.

Jeddah's growth exceeded anticipated plans for infrastructural development and urban control. In response to this growth, a master plan was created by the Municipality of Jeddah. The 1973 master plan for Jeddah predicted a population of 1.6 million for 1990 and defined a growth policy to keep residential development within the confines of the ring road of the city. The city has developed from the central "old Jeddah" in a north/south pattern with most of the residential areas in the north and the industrial areas to the south. The development also extended out into the sea along the reef flats to utilize the attractive coastal areas for the Corniche and residential areas.

The city now consists of 21 districts. Each district represents part or all of the 14 sub-municipalities of the city, namely: Al Mina, Al Aziziyah, Bani Malek, Al Salamah, Thager, Al Jamea, Obhor, New Jeddah, Port, Sharafia, Al Rawais, Al Hindawiyah, Al Balad and Khozam.

4. *Jeddah's present roles*

The amount of cargo unloaded in Jeddah port was more than 150,000 tons in 1946. This increased to over 8 million tons in 1977. Today the port handles more than 16 million tons, with a single jetty in Jeddah. The Islamic port handles 1,200 tons per day. The Jeddah port handles over 60% of the Kingdom's imports. The port can handle 58 ships at one time at its 11.2 kilometres of docking facilities.

Pilgrims have been arriving in Jeddah for hundreds of years. In 1883 there were about 27,000 pilgrims coming through the port facilities. With the development of modern transportation there are over 1.6 million pilgrims arriving from abroad. In addition to the visitors coming to the Jeddah area on pilgrimage to Mecca and Medina, there are even greater numbers arriving as tourists and on business.

Tourism in Jeddah is a big business. The city alone attracts over 50% of the internal tourism to the Kingdom. For an area that was once very difficult to live in, the city is now very attractive for visitors from the other parts of the Kingdom. Part of this, of course, is due to the beautiful coastal areas of the Red Sea, and the more comfortable temperatures of the area compared with other parts of the Kingdom. In addition, Jeddah is a cosmopolitan city which attracts shoppers; there are more than 200 shopping centres in the city. The city has a 110-kilometre Corniche, from the very south end of Jeddah to the north of Sharm Obhor, which has many public sites for recreation activities. The facilities for tourism include more than 25 hotels with over 7,000 rooms. In addition, there are 3,000 furnished flats for rent plus 1,200 cabins and villas along the coast.

As with the pilgrims, tourism is very seasonal; more than 500,000 visitors come during the spring holidays compared with 250,000 throughout the rest of the year.

Jeddah's industrial growth and diversity of activities are similar to most equal-sized cities in the world. It is not a heavy industrial area, as most of the petroleum processing occurs in the Eastern Province of Saudi Arabia and in Yanbu. However, Jeddah includes a mix of activities. There are now over 650 industries inside and outside the industrial area.

2. *Climate*

The climate of Jeddah is related to the city's location on the Red Sea. The city's climate is between the Mediterranean and the monsoon-type of climate. However, the climate can be described as arid. Relative humidity averages monthly maximums of between 85% and 89%, but during certain periods, it may reach 90%. This humidity is coupled with an average monthly temperature of about 30°C.

Rainfall is erratic and characterized by sudden torrential cloudbursts, leading to flooding and rapid run-off of approximately 30% of the rainfall. Accumulated information on the annual rainfall in the city of Jeddah is shown in table 7 and illustrated in figure 11.

The prevailing winds blow consistently from the north-west in the Jeddah area, in spite of the fact that the southern portion of the Red Sea receives winds from the south-south-east during the winter season. The winter winds converge to the south of Jeddah, resulting in a net inflow of surface waters during the winter season and a rise in sea level of 0.5 metres in the winter relative to the summer (20).

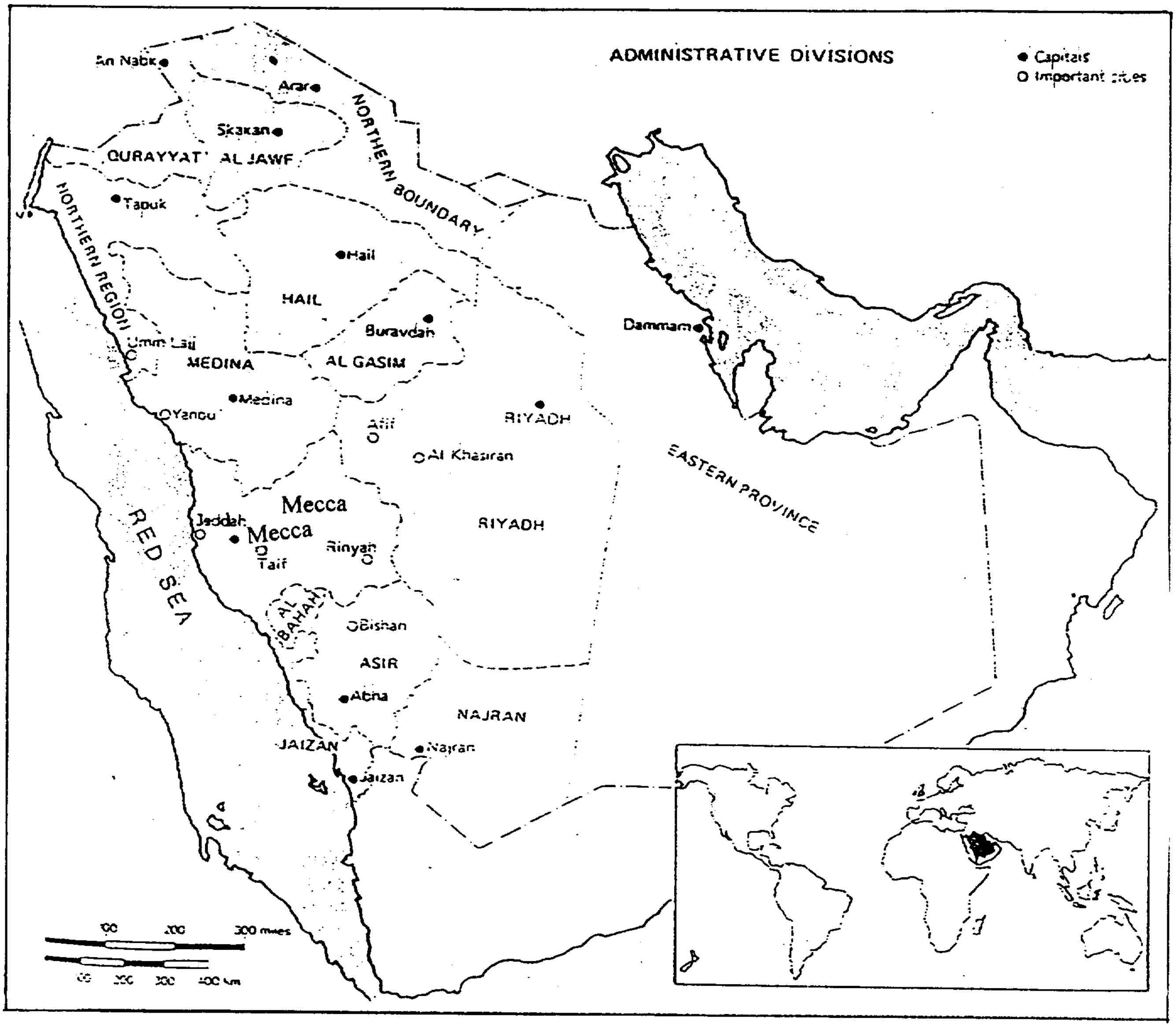
3. *Population growth and urban development*

From 1947 to 1956, Saudi Arabia experienced the first of several economic booms, as a result of the discovery and export of oil in the Eastern Province of the Kingdom and later by the quadrupling of oil prices during the 1970s. Much of the new oil wealth was spent on development projects in the Western Province, and there was a dramatic increase in construction throughout the region, but especially in Jeddah. As a result of the general increase in prosperity in the Western Province, the traditional role of Jeddah as the country's principal port was strengthened. The city also developed as a major regional and commercial centre. This development led to the expansion of Jeddah from a walled coastal city to a thriving modern city.

Originally the city of Jeddah was a small town, on the eastern coast of the Red Sea, which covered an area of about 1 square kilometre and was inhabited by 5,000 citizens in the year 1650. The population had grown to 20,000-30,000 residents by the year 1831. A century later (1945), the population for the city was estimated at 30,000-40,000. By 1961, the city had grown to 150,000, and to 250,000 in 1966. These figures represent an average annual increase of 11% over the period from 1947 to 1966. This rate of growth was maintained for the next five years, leading to a 1971 population of 404,650. Between 1971 and 1978, the city's population more than doubled, to a 1978 total of 915,800, an average annual rate of growth of 12.4%. Although the general slow-down in economic activity in the Kingdom during the early 1980s led to a reduction in the rate of growth from the very high levels of the boom years, Jeddah's population continued to increase at almost 3% per annum from 1981, to reach a total of 1,312,600 in 1987 (Ministry of Municipal and Rural Affairs, 1989).

Economic activities and urban migration over the last three decades caused the city to expand from 1.90 square kilometres in 1946, to an area over 1,200 square kilometres as of 1991-1996. The rapid increase in urban growth of the city started in 1981, owing to expanded commercial and industrial activities. However, there was a notable decrease in the rate of the expansion of the city during the period 1956-1961, which can be attributed to the closing of the Suez Canal and to inflation. Historical urban expansion as well as current growth is shown in figures 12 and 13.

Figure 10. Location of Jeddah city within the Kingdom of Saudi Arabia



2. *Legislation, enforcement and advocacy*

The continuing efforts of ESCWA to assist countries that are working on developing water legislation should also include Gaza. Advocacy through a regional conference at the highest levels could also help to persuade government officials to act quickly in passing enforceable legislation on water pollution control.

3. *Community management of water supply and sanitation*

The extremely limited resources in Gaza and the seriousness of the situation with regard to water pollution requires immediate action which cannot even wait for government decisions, large infrastructure projects and detailed master plans. More data are certainly needed on specific aspects of water pollution, but much of this can be collected, analysed and used at community level to assist in solving problems on a smaller scale. Recent work by USAID on "Community involvement in the management of environmental pollution" in Tunisia has shown how community participation in assessment, planning and implementation of small-scale projects can greatly improve the public health situation.

In order to better understand attitudes towards water use and pollution, a better understanding of "knowledge, attitudes and practices" of households, government officials and other involved parties is necessary. In addition, specific data on current household water use and disposal patterns are needed in order to assist planners in targeting specific groups for education and information campaigns. A study combining these various levels of information could be carried out or funded by ESCWA, perhaps using the participatory approach noted above as a way of further assisting in testing and development of the methodology.

dollars have been allocated for various projects, many of which bring their own staff members, either seconded or working independently. There was some attempt, through the Water Resources Action Plan Task Force, to monitor activities of government and aid agencies to avoid overlap and duplication.

According to a recent report, the general lack of understanding and concern about the value and scarcity of water resources is likely to be a major constraint on sustainable water resources management (10). Since the takeover of the Palestinian Authority and influx of aid funds, there has been a tendency to assume that all assistance will come from outside. However, in Gaza, participation of the community is crucial to making the environment sustainable. Practices and beliefs needs to be changed in order to reduce wastage and pollution. People need to understand the real causes and extent of water scarcity and pollution. At present, there is little environmental education and awareness of issues, especially outside of the refugee camps where UNRWA has a school education programme. People also need reassurance that changing their practices will be complemented by improvements in service levels. Community-level surveys showed that one of the main concerns was water scarcity and low pressure, but that understanding of the reasons behind this was limited (10).

One of the major resources in improving environmental health is the community itself, the "stakeholders". In Gaza, there have been two forces at work affecting the level of community involvement. First, the former military authority ruled with an iron hand and there was no room for community input into "government" decisions and, in the refugee camps, water, sanitation and solid waste services were generally provided by UNRWA with outside funding. Secondly, communities found under occupation that if they wanted to make any changes, they had to come from within. Some local Islamic groups and other NGOs did start projects, often with assistance from NGOs.

A brief outline of institutional responsibilities for water pollution-related activities is given below. In addition, all major projects must be approved by the Government of Israel. If projects are funded by external agencies (as is almost always the case), the specific requirements of that agency must also be met in the project design and implementation.

E. ENVIRONMENTAL CONTROL

The Environmental Planning Directorate in the Ministry of Planning and International Development is responsible for "environmental activities", including solid waste and wastewater. At present, it only has a few staff members, but from early 1997 will have 21 professional staff funded from a variety of sources and projects. The Environmental Planning Directorate plays an advisory, regulatory role, and does not directly implement infrastructural projects.

Municipalities, town councils and, in the case of refugee camps, UNRWA, are responsible for solid waste management. A solid waste master plan is being developed through a project funded by the German Government, with a consultant based in the Environmental Planning Directorate. Environmental education projects are funded in Gaza by various NGOs.

Abstraction and distribution of water is the responsibility of the municipalities, town councils and UNRWA. Private well operators also abstract and distribute drinking water. Domestic water supply wells are often not drilled in the exact locations in which permission for drilling has been given by the appropriate officials of the Palestinian Authority. These agencies normally obtain funding from external aid agencies and, theoretically, need permission from the Palestine Water Authority and the Israeli Government for their projects. However, practically, municipalities often still make their own decisions, plans and negotiations with donors.

(a) Obtain more water from Israel or other outside sources (the Nile in Egypt has been suggested);

(b) Construct desalination plants (extremely expensive, requiring high technology and skilled manpower);

(c) Increase rainwater collection.

Obtaining additional water from outside sources requires political and economic decisions beyond the scope of this study. Desalination is an extremely expensive alternative for Gaza. Rainwater collection is being addressed by the current study being carried out in Gaza by American consultants.

Water conservation remains the major short-term solution to reducing the overabstraction of the aquifer. If current figures of domestic consumption are correct, at 50-100 lpcd, there is little scope for Gaza households to reduce their already limited consumption. The focus must be on reducing wastage through control of leakage and illegal connections, and using various methods to encourage farmers to reduce water use and losses. Policy and technical decisions must be made concerning the control of agricultural water use.

Municipalities, town councils and UNRWA have obtained funds from outside sources to upgrade some of their water distribution and metering networks. Several local and international NGOs are working with farmers and communities to develop rainwater collection systems and improve farming methods to preserve water use: Save the Children, the Palestine Hydrology Group, and the Palestinian Agricultural Relief Committee are just a few. The Ministry of Agriculture is also involved in this effort, but their specific plan of activities is not known.

It has been suggested that separate, private sources should be developed for freshwater supplies only. This is to some extent already occurring on a private basis and should be further investigated.

2. *Domestic and municipal wastewater*

Individual municipalities, town councils and UNRWA have all obtained some funds, or promises of funds, to develop sewage collection treatment and disposal systems. Although more funding is undoubtedly needed, these projects, once completed, should reduce groundwater pollution and, in the case of sewage treatment, provide clean effluent which can be used for irrigation. The Swedish Government is funding the upgrading of the Jabaliya treatment plant, but the project is still in the design and feasibility stage. UNRWA is funding some upgrading of the Gaza city plant, but, according to UNDP engineers, this may not significantly improve water quality as the plant is still too small for the city. Rafah city has obtained $2 million from the European Community to upgrade sewage networks and enlarge the treatment plant, but has run into problems in obtaining the land needed for this purpose. USAID (United States Agency for International Development) is funding through UNRWA a $40 million wastewater project for Gaza city, including an emergency phase which has already been completed to control storm water drainage and overflowing.

3. *Agricultural wastewater*

The Environmental Planning Directorate has recommended that many chemicals currently used in agriculture be prohibited, that agricultural extension services be improved, and that incentives for farmers to reduce use of agro-chemicals should be developed. To date, these recommendations have not been implemented. Save the Children, in collaboration with the agricultural extension service, has embarked on an ambitious programme to reduce the level and toxicity of pesticides used, including a public information leakage into surrounding groundwater) and size (causing overflowing). Overflowing sewers are also caused by limited capacity, especially in rainy winter months, and blockage by indiscriminate dumping of solid waste.

UNRWA and UNDP, in cooperation with municipalities, built several treatment plants in Gaza. However, although sewage is conveyed to them, only one small plant in Rafah is currently operating. Most of the plants never worked properly. In addition, owing to the expansion of urban areas, most are now too close to developed areas. Generally, the settling ponds after treatment store untreated effluent, which eventually overflows into surrounding land, infiltrating groundwater and in some cases ending up in the sea. There is no system of collecting fees for operation and maintenance of sewerage works. Original designs were in some cases faulty, technical expertise is lacking, and operational responsibilities are not clearly defined.

In some cases, raw wastewater is used to irrigate crops, but there are no specific data on how widespread this practice is or what crops are irrigated.

According to a 1993 Environmental Profile regarding agricultural wastewater, high consumer quality demands, together with pest prevalence in monoculture crops in greenhouses and open fields without crop rotation, have forced farmers to apply fertilizer, pesticides and other agro-chemicals on a large scale. There is little control or extension advice on the use of these chemicals. For example, over 155 different types of pesticides have been identified, with very high levels of active ingredients compared with other countries. Farmers are not aware of the dangers and risks of overspraying and the risk of building up pesticide resistance. The response to a new or persistent pest is simply more spraying. In addition, instructions with chemicals are usually in Hebrew, not understandable to Arab farmers. Persistent hazardous chemicals such as malathion and methyl bromide are used in high doses.

There is no control on application of agro-chemicals or dumping of unusable stocks. It has not been unknown for outdated Israeli or imported chemicals to be used, knowing or unknowingly, on crops in Gaza.

Most written sources minimize the threat of groundwater contamination from industrial sources, in particular the industrial waste dumping and wastewater. However, a 1994 report on wastewater treatment and reuse concluded that inoperable collection and treatment systems in the industrial areas were the most urgent public health issue. No data were included in the report to back up the assertion, however. Some aid officials have expressed concern about the lack of proper industrial treatment of effluent, lack of government control, and lack of expertise in handling industrial waste. The Palestinian Authority is reportedly following WHO guidelines in this respect, but there is no enforcement with industry. Solid waste from industry is dumped indiscriminately and sometimes blocks drainage canals.

Solid waste collection in Gaza is estimated at 418,000 cm annually; this accounts for only about half of all waste generated. Solid waste collection and disposal for a given household can follow more than one method:

(a) Dumping in the street, resulting in blockage of drainage canals;

(b) Neighbourhood collection, with dumping at municipal waste dumps, resulting in leaching into groundwater;

(c) Neighbourhood collection, with indiscriminate dumping, often on the dune areas, leaching into groundwater;

(d) Dumping in disused boreholes, causing direct contamination of groundwater.

wells in refugee camps are probably the result of pollution from untreated domestic wastewater (19). In a study for UNRWA, CDM also found that the nitrate levels of domestic wells located in refugee camps (with poor sanitation) were 3-5 times those found in wells serving agricultural areas (10).

Although it is well known that high nitrate levels can cause "blue baby disease," there are not sufficient data available to prove that this disease is prevalent in Gaza. UNRWA is currently testing children for indications of the disease and, although there is no firm evidence as yet, indications are that children are being affected by the high levels.

3. *Bacteriological contamination and worm/helminth infestation*

Over the past few years, the early winter rains have caused flooding of raw sewage in Gaza city, contributing to outbreaks of cholera. Diarrhoea is one of the major diseases in Gaza. According to a review of UNRWA records, children suffer four episodes of diarrhoea per year; 50% of the children are reported to be anaemic (10). The Ministry of Health has reported very high levels of bacteriological contamination of water supplies within the distribution networks.

Helminth infections can be transmitted through skin contact, ingestion of contaminated water or through consumption of contaminated agricultural products. These diseases are extremely prevalent in Gaza, although there are no data available showing the specific cause or causes. Analysis of data in 1994 based on clinic visits indicated that over 85% of Beach Refugee Camp children in Gaza were infected with ascariasis and 75% with Giardia lamblia. Analysis of UNRWA data indicated that in the same camp 2.6% of blue collar workers and 27.2% of white collar workers were infected with ascariasis. In the 3-4 year-old category, 50%-85% of children were infected. The presence of ascariasis is often a good indicator of other helminthic parasites, so people could be infected with more than one helminth at a time. Although there were not major outbreaks of typhoid and paratyphoid fevers, between one and six typhoid cases/week were reported in Rafah Camp in a six-week period in 1991.

Until recently, there was little analysis of other contaminations of groundwater, including heavy metals, pesticides and other organic chemicals. In 1995 and 1996, the Environmental Planning Directorate carried out a pilot study of 20 samples from 13 wells in areas where industrial pollution was suspected: traces of several organic compounds and heavy metals were found.

B. SOURCES OF WATER POLLUTION

All water sources—sea, surface, and ground—are polluted in Gaza, from almost all possible pollution sources, as outlined below.

Sea water is polluted by:

(a) Domestic wastewater flowing from non-operational sewage treatment plants;
(b) Agricultural wastewater;
(c) Solid waste leachate from indiscriminate dumping;
(d) Hazardous waste dumping close to or in the sea;
(e) Domestic agricultural and solid waste pollutants flowing in from Wadi Gaza.

Surface water (Wadi Gaza) is polluted by:

(a) Municipal wastewater—domestic and storm drainage;
(b) Agricultural wastewater;
(c) Solid waste leachate.

(a) Switch to more water-efficient horticultural crops (fruits, vegetables and flowers) with high export value;

(b) Rehabilitation of existing wells and irrigation systems, resulting in fewer distribution losses (currently estimated by Bruins at 20%);

(c) Reduction in water quality, limiting water of sufficient quality for irrigation;

(d) Decrease in land area available for irrigation owing to urbanization and/or soil damage;

(e) Strict controls on land area, cropping patterns imposed by the Palestinian Authority or voluntarily by farmers;

(f) Increased use of rainwater collection in greenhouses;

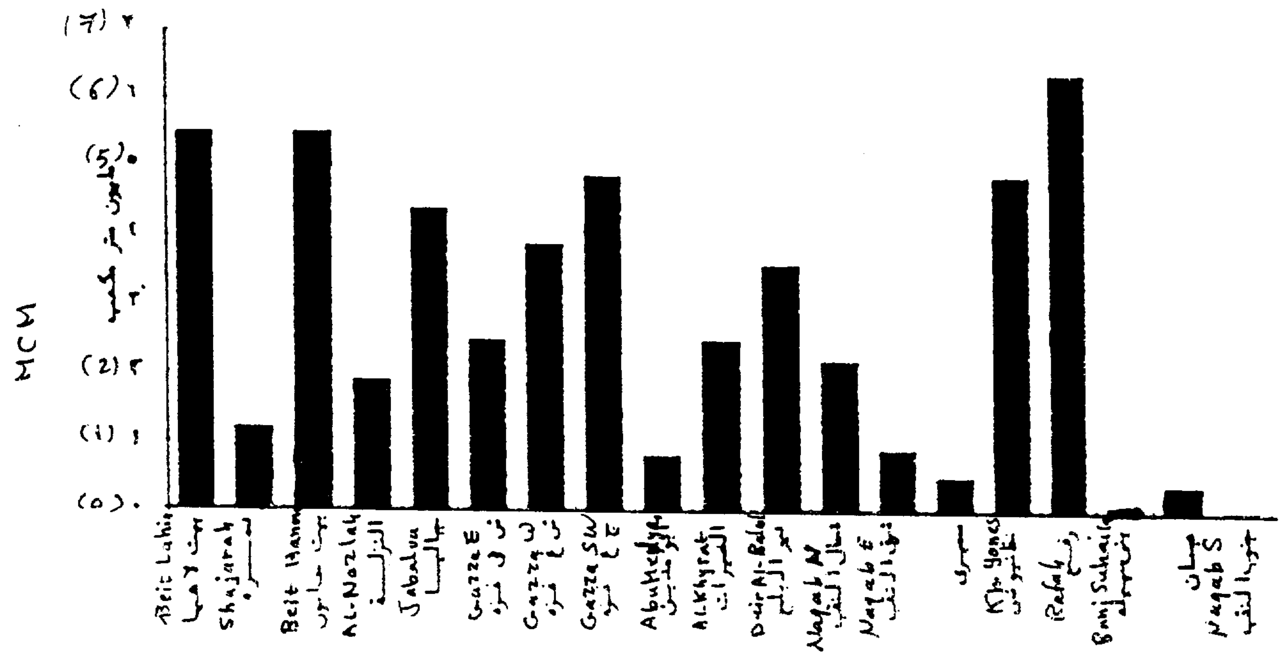
(g) Difficulty in reaching and/or developing viable export markets.

No specific studies on agriculture in Gaza were available. However, several sources point to the trend to increase horticultural crops, which use less water, but require higher inputs in terms of fertilizers, pesticides and fumigants.

E. INDUSTRIAL WATER SUPPLY

Although no official data are available on industry in Gaza, most sources estimate that present industrial water use is minimal, only 1%-2% of total water use. However, as part of overall economic development plans for Gaza, at least one industrial estate is planned to house light textile, and possibly other, industries. Industrialization is one of the proposed solutions to high unemployment and the lack of natural resources in Gaza, so water demand for industrial purposes may well increase.

Figure 9. Annual water consumption in agriculture in the Gaza Strip (mcm)



Source: Y. Abu Mayleh, water requirements for Gaza Strip, Water Science Magazine (14th issue), October 1993 (in Arabic).

The boundaries and names shown on this map do not imply official endorsement or acceptance by the United Nations.

Groundwater is provided from the coastal plain aquifer, which stretches the full length and width of Gaza, although it varies considerably in depth and occurrence. Recharge of the aquifer varies widely over the area, and can come from one or all of the following sources: rainfall, sea water, deep stagnant groundwater, inflow from surrounding areas of Israel, infiltrating surface water, irrigation return flow and wastewater. The quality of water, therefore, can vary greatly, even between small distances. Total groundwater recharge estimates vary widely, from 20-125 mcm/year (table 6), but estimates of overall water use are all within a similar range of 105-130 mcm/year. Experts agree that the groundwater in Gaza is being abstracted at a rate that far exceeds its recharge rate, with estimated lowering of the groundwater table of between 20 and 50 mm/year (figure 7).

TABLE 6. GROUNDWATER RESOURCES AND ALLOCATION IN GAZA

Renewable groundwater resources	Total demand	Demand as % of renewable resources
20-125 mcm/yr	108 mcm	86 to 540
35-40mcm/yr	125 mcm	300
-----	110mcm	
40 mcm/yr	106 mcm	260
25-50mcm/yr	129 mcm	258 to 516

Source: H.J. Bruins, A. Tuinhof and R. Keller, *Water in the Gaza Strip*, Identification of water resources and water use, recommendations for Netherlands assistance, Hydrology study, final report, Government of the Netherlands, Ministry of Foreign Affairs, Directorate General for International Cooperation, September 1991.

The Environmental Planning Directorate of the Palestinian Authority, in its updated report in 1996, lists the groundwater deficit at "only" 16 mcm/year. However, it then further distinguishes between "fresh groundwater" (chloride content less than 500 mg Cl/L) which can be used for potable water. According to the Directorates calculations, the freshwater deficit is 22 mcm/year.

Groundwater is tapped from the 2,500 boreholes previously registered with Israel; and approximately 1,500 boreholes have been drilled, mainly for irrigation purposes, without permission since the takeover of the Palestinian Authority.

Most sources agree that domestic water use is approximately 25% of overall use, with industrial use negligible and most of the remaining 75% for agriculture. It should be noted that water use in Gaza does not necessarily reflect actual water demand. Although for years extraction in Gaza has outstripped renewable resources, there were restrictions under the occupation government in order to limit the over abstraction. Since the arrival of the Palestinian Authority, it has been difficult, both in political and practical terms, to limit the abstraction of water.

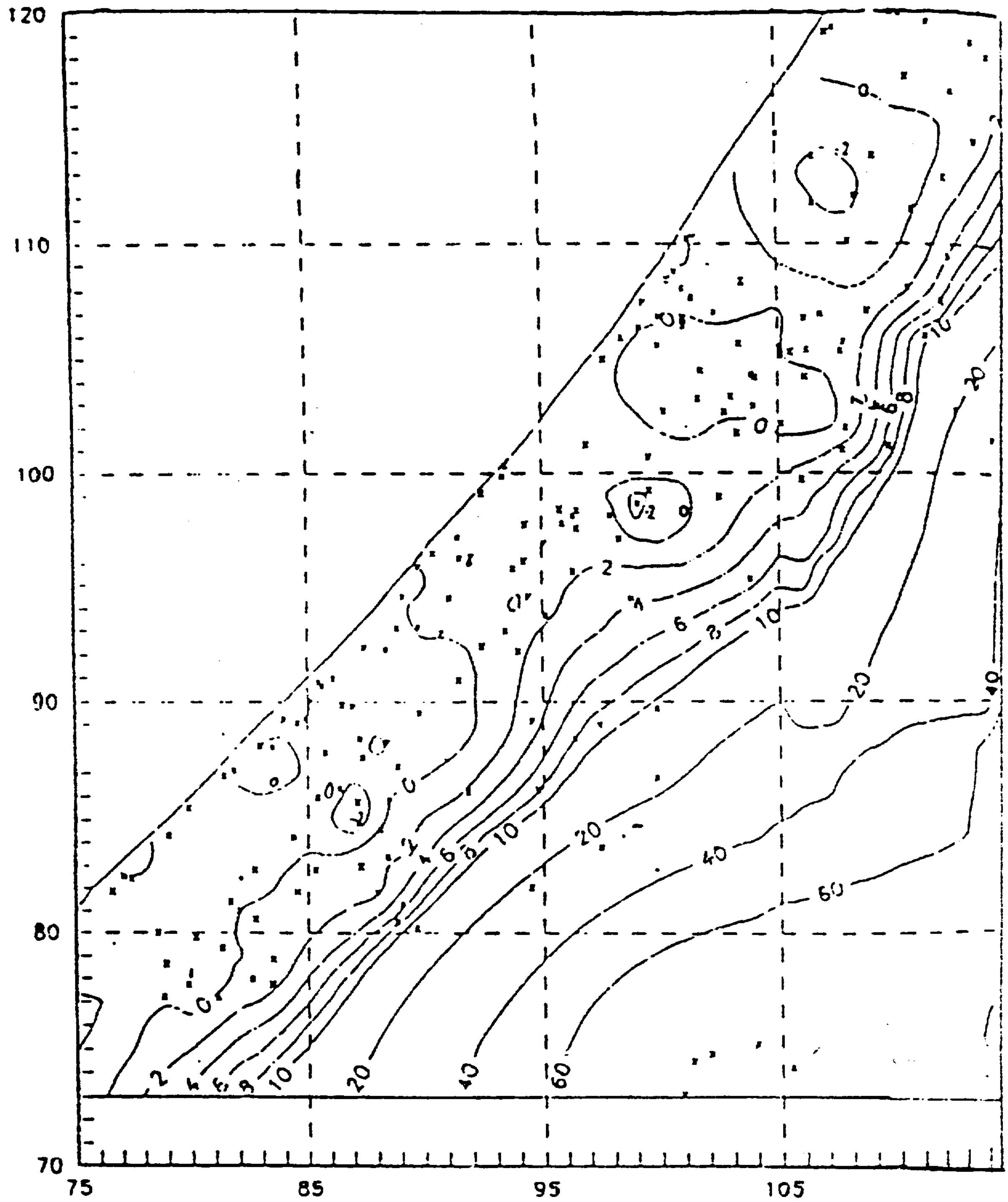
C. DOMESTIC WATER SUPPLY

Approximately 90% of households in Gaza have access to water within their homes, and most have rooftop or underground storage tanks to compensate for intermittent supplies, sometimes as little as one hour per day. All domestic water supply comes from groundwater, and one household may receive its supply through one or more of the following methods:

(a) Piped supply directly to home with legal connection;

(b) Piped supply directly to home made with illegal connection (either illegal tapping of supply or broken meter);

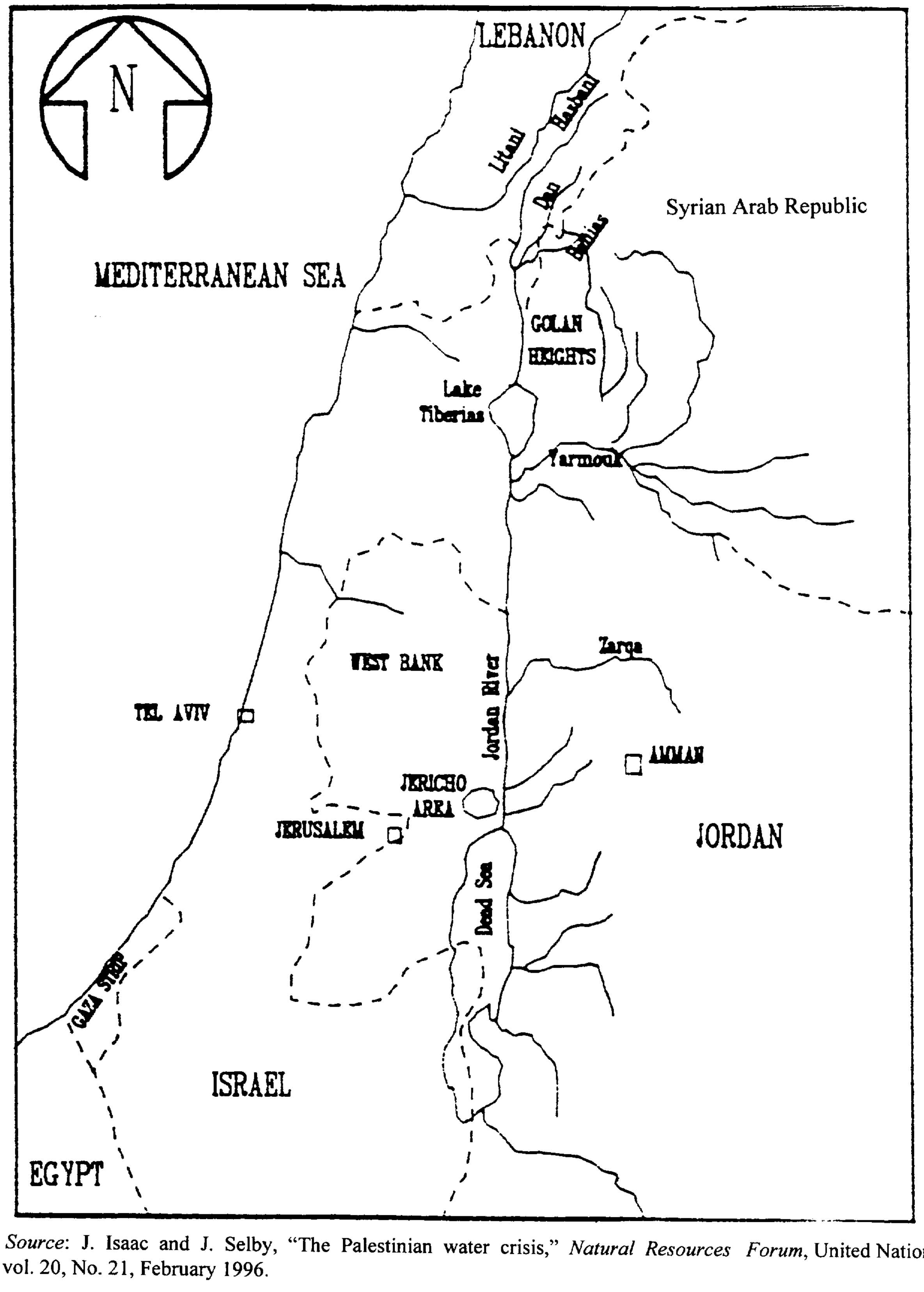
Figure 7. Water table contour map in Gaza Strip



Source: Y. Abu Maylek, Water requirements for Gaza Strip, *Water Science Magazine* (14th issue), October 1993 (in Arabic).

The boundaries and names shown on this map do not imply official endorsement or acceptance by the United Nations.

Figure 5. Gaza location map



Source: J. Isaac and J. Selby, "The Palestinian water crisis," *Natural Resources Forum*, United Nations Journal, vol. 20, No. 21, February 1996.

The boundaries and names shown on this map do not imply official endorsement or acceptance by the United Nations.

3. *Agricultural water supply*

The Ministry of Irrigation issues permits for borehole drilling, and the Ministry of Agriculture is responsible for farm-level activities such as construction and maintenance of canals, training and support for farmers in efficient irrigation practices and proper use of pesticides, herbicides and fertilizers.

4. *Industrial water supply*

The Ministry of Industry provides borehole drilling permits for industrial use and oversees industrial activities, but reportedly takes no active role in enforcing regulations concerning industrial effluent. The Water Pollution and Control Department of the Ministry of Irrigation theoretically controls industrial pollution, but has no enforcement powers.

5. *Environmental protection*

The new Ministry of State for Environmental Affairs acts so far only as an advisory, coordinating body on environmental issues. It is expected that the Ministry will be responsible for setting up environmental standards and carrying out pollution monitoring programmes and pollution protection measures. At present, the Ministry is mainly occupied in developing the Strategy for the Environment.

6. *Water quality monitoring*

The agency with the main responsibility for water resources quality monitoring is the Water Pollution Control Department of the Ministry of Irrigation. The Ministry of Housing and Utilities operates a water quality laboratory for monitoring drinking water quality in Damascus. The Ministry of Health tests water quality as needed when there is an outbreak of a water-related disease.

Random samples of groundwater were tested in 1991 from eight groundwater and surface water sources used for irrigation in the Al-Ghouta Plain. Results indicated a range from 348 to 582 E. Coli/100 ml for the groundwater and 2,400/100 ml for river samples, all for above acceptable levels for irrigation (16). Studies carried out in 1988 indicated nitrate concentrations ranging between 5 and 50 mg/L in boreholes, with only a few samples above the acceptable level of 50 mg/l. This contamination could be from fertilizers and/or domestic wastewater, depending on borehole location. No significant signs of contamination by heavy metals were found in a limited number of sample boreholes. Contamination of shallow groundwater in the Damascus depression was found by organochlorine pesticides, but no studies were done of organo-phosphorous and complete pesticides .

B. POLLUTION CONTROL MEASURES

Two current Government activities which address the issue of water pollution will provide useful information for planners in developing programmes to institute water pollution control measures. The activities are: the development of a Strategy for the Environment by a committee of representatives of various ministries and the development of a Strategy for Environment Health by the Ministry of Health. These are expected to be finalized and approved in 1997.

The problem of pollution from domestic wastewater will be greatly alleviated in 1997 by the completion of the Damascus Wastewater Treatment Project, which includes upgrading the sewerage network, building a sewage treatment works and pumping treated sewage to the agricultural areas of the Al-Ghouta Plain. A main trunk line will carry domestic and municipal sewage from Damascus city to a new sewage plant at Adhra 22.5 km away. The plant, with a design capacity of 485,000 cm/day, will employ an activated sludge process, followed by sedimentation tanks and tertiary treatment, including chlorination. The resulting sludge will be dried and used as fertilizer and soil conditioner, thereby reducing the need for chemical fertilizers. The quality of the effluent is designed to meet guidelines for effluent reuse in agriculture and in the first phase will be sufficient to irrigate a net area of 13,840 hectares. The second phase will cover the full area or 16,600 hectares presently irrigated by domestic wastewater carried by the Barada River to the Al-Ghouta Plain.

The plant is designed to achieve a treated effluent with a BOD of 20 mg/l and suspended solids of 20 mg/l. The activated sludge process will not remove helminths, which constitute the major public health risk in agricultural reuse schemes. Although there are as yet no specific plans as to how to manage, train and regulate wastewater reuse, a Master Plan for Wastewater Treatment and Reuse is currently being developed. A study on the environmental impact of the sewage treatment works is also under way. Building national capacity for the development, management, operation and maintenance of wastewater works in the country is recognized by officials as a priority and is being addressed through various training courses.

Once the new sewage treatment works is in operation, there are concerns that farmers will not be willing to pay for treated effluent and will continue to pump water from the Al-Ghouta basin or directly from the Barada River. The Government plans to control strictly these activities, and this subject will be addressed in the Master Plan for Wastewater Treatment and Reuse.

At present, there are no environmental controls over discharge of sewage from smaller towns and villages, and priority in pollution control is at present being given to the major cities in the Syrian Arab Republic. Plans to upgrade rural systems are being incorporated in the Strategy for the Environment.

The Government is addressing the subject of overuse of agro-chemicals through its programmes to increase agricultural production and increase irrigation efficiency. However, more data on water quality are

TABLE 5. DAMASCUS CITY: DOMESTIC WATER SUPPLY

Source name	Type of water	Amount provided (mcm/day)
Feigha Spring	Groundwater	360,000
Barada River (upstream of Damascus)	Surface water	90,000
Boreholes and springs	Groundwater	150,000
Total		500,000

Source: Direct contact with Government officials.

The Ministry of Irrigation estimates the unaccounted-for-water as amounting to about 35% of the municipal water supply. Reports indicate that domestic consumption is approximately 164 lpcd and rapidly increasing, but it is not clear if these are just general estimates or amounts based on actual, direct studies of domestic use (32). Domestic charges for water are subsidized, with a sliding scale of price depending on the amount used. Rural areas surrounding Damascus city are supplied by individual or communal boreholes.

The Damascus basin holds one of the most ancient irrigation systems in the world, using mainly flood irrigation. A complex system of main and secondary canals carries raw wastewater from the Barrada River and, in some cases, mixes it with groundwater pumped from boreholes to irrigate approximately 66,000 hectares of land for production of vegetables and fruits. Drainage from the Awaj River also supplies irrigation water.

There are several industrial areas in Damascus, mainly on the outskirts of the city on the southern road to Amman. There are approximately 250 tanneries, and 170 small factories of other types, including wool-processing workshops and textile production. Many of these small enterprises are located in residential areas. There are also several large, State-owned factories including textiles, paper, metal treatment, canning, cement, fertilizers and insecticides. By law, factories are only allowed to use the municipal water supply for drinking water purposes and are required to develop their own source (i.e., boreholes) for industrial purposes. Industries are charged LS 12/cm for municipal water, four times higher than the standard domestic rate, to discourage overuse. Permission is required drill boreholes.

2. *Pollution of water resources*

The Government of the Syrian Arab Republic has in recent years placed high priority on combating water pollution and other environmental issues. There are several ongoing projects and studies which will assist the Government in planning for water resources protection and development. One of the main constraints on planning and assessment of the situation is the lack of data on causes of water pollution and water quality. An overview of the sources of pollution is outlined below, followed by a summary of the health impact, water quality and a review of pollution control measures. Legislation and institutions affecting water pollution issues are also reviewed.

The three main users of water—domestic, agricultural and industrial—are also the main causes of water pollution in the Syrian Arab Republic. Damascus city has one of the oldest sewerage networks in the world, with some parts of the system dating back to Roman times. At the household level, 90% of homes have safe disposal of wastewater through sewerage connections. However, this network, covering 43 sq km of the city, carries the combined flow of untreated domestic and storm water and feeds directly into the Barada River, then spreads through a canal system directly to the Al-Ghouta Plain for irrigation, causing health risks to both farmers and consumers. Drainage from irrigation with domestic wastewater also pollutes the groundwater in the Al-Ghouta Plain, which is used for irrigation and domestic water supply. The older parts of the Damascus sewerage system are badly in need of repair; this causes leakage into the

II. POLLUTION CONTROL IN DAMASCUS BASIN

A. WATER POLLUTION SOURCES

1. *Damascus basin water resources and utilization*

The Greater Damascus area has a population of approximately 4 million, including the central urban area, outlying industrial and suburban areas, and rural agricultural areas surrounding the city. The Damascus basin covers an area of approximately 10,600 square kilometres.

The main source of surface water is the Barada River, which flows from the Anti-Lebanon hills in the north-west through Damascus city out to the Al-Ghouta Plain, where it is mainly used for flood irrigation. The river flow is generally very low, as water from the river source (Barada spring) is tapped to supply municipal water for Damascus. It usually dries up completely in the summer from Damascus city onwards; the river flow is mainly made up of domestic wastewater.

The main groundwater sources in the upper Damascus basin are the two main springs, Feigha Spring and Barada Spring, both of which in the past fed the Barada River, but are now tapped directly at the source and flow by gravity to feed the Damascus city distribution network. The Barada spring, the source of the Barada River, has an average discharge of 2.1 cm/second, varying between 1.3 and 3.0 cm/second throughout the year. Lower down the river, discharge from Feigha spring ranges from 1.5 cm/second in the summer to 15 cm/second in the winter, with average discharge of 7.7 cm/second .

The Damascus basin includes one very important aquifer, which varies in depth from 1-6 metres in the western part to 35-50 metres in the eastern part (figure 4). It is fed mainly from infiltration from surface water, in addition to groundwater flows and surface infiltration from rainfall (3). In the Al-Ghouta Plain, thousands of boreholes have been drilled, mostly without permits, for industrial, agricultural and domestic water supplies. Estimates of the number of boreholes are as high as 23,000 (13). Although it makes up only 2% of the total area of the Syrian Arab Republic, water resource utilization in the Al Ghouta Plain is estimated at 480 mcm per year, more than 25% of the total groundwater resources developed in the country (3). A summary of water sources and their uses is given in table 4.

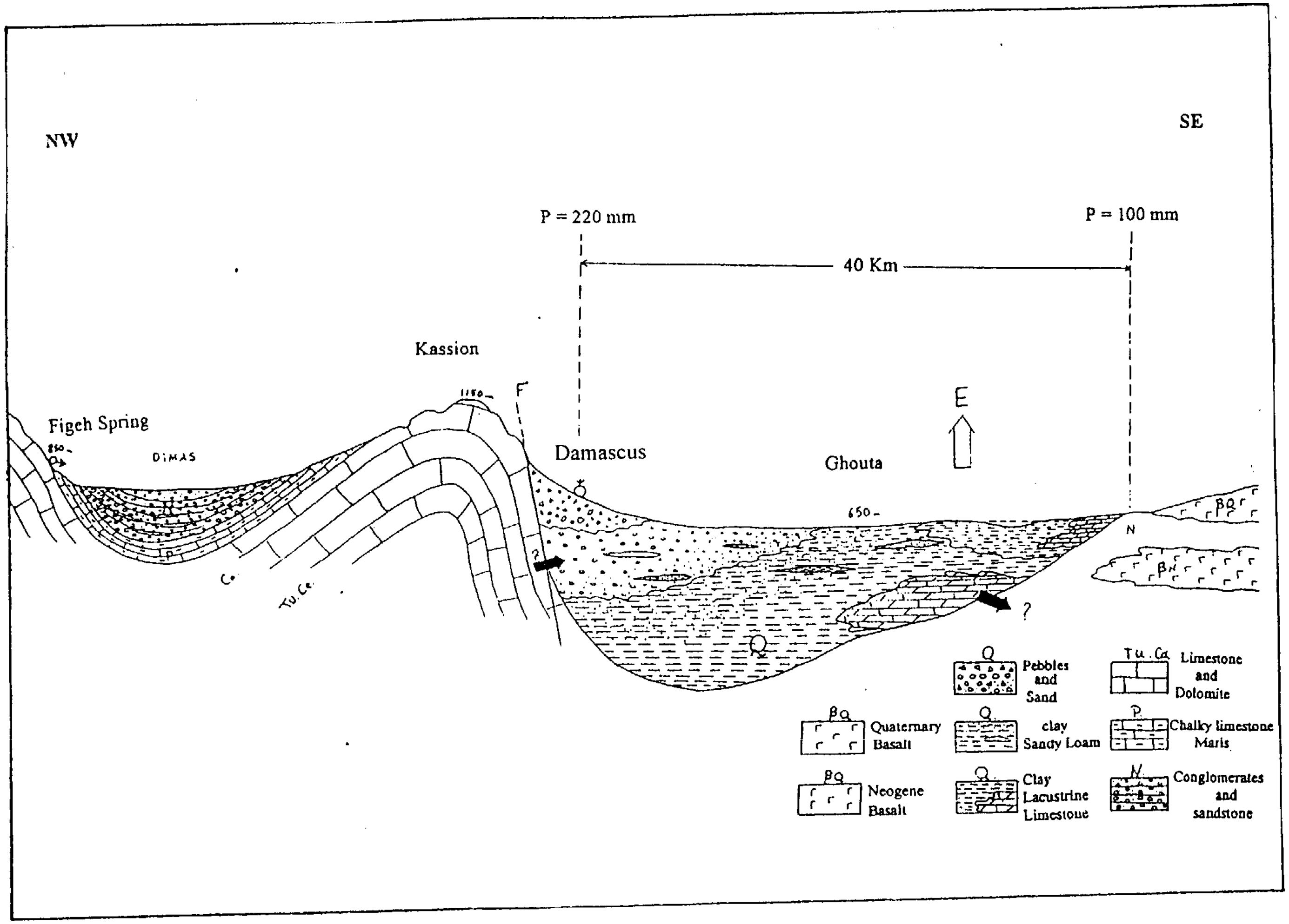
TABLE 4. DAMASCUS BASIN: WATER SOURCES AND UTILIZATION

Type of source	Source name	Use
Groundwater	Feigha Spring	Domestic
Groundwater	Barada Spring	Domestic
Groundwater	Boreholes	Domestic Irrigation Industrial
Surface water	Barada River	Domestic Irrigation

Source: A.J. Manna, 1994, "Environmental impact of dual purpose plants", in *Desalination and Water Reuse*, 4(1): 46-49.

The Feigha Spring was originally the only source of domestic water for the city of Damascus and still remains the main source. It is supplemented by other boreholes and springs and by withdrawals from the Barada River, owing to increasing water demands.

Figure 3. Cross-section of studied area



Source: Isotope field applications for groundwater studies in the Middle East, Proceedings of the final coordination meeting of a regional technical cooperation project held in Ankara, Turkey, 21-25 November 1994.

The boundaries and names shown on this map do not imply official endorsement by the United Nations.

2. *Climate*

The climate of Damascus is predominantly Mediterranean, with relatively warm dry summers and cool wet winters. The temperatures rarely fall more than a few degrees below freezing in winter and seldom exceed 45°C in summer. The rainy season starts in late October and continues through March and April; the prevailing westerly winds obtain moisture from the Mediterranean and deposit this moisture over the western uplands. Rainfall is not distributed uniformly over the basin owing to the influences of the two mountain series which form a barrier to the passage of humidity from the west. Average annual rainfall exceeds 600 mm in the western part of Damascus basin. In the central parts, rainfall decreases to 300 mm, while in the eastern parts it is only 125 mm.

E. GEOLOGY, HYDROLOGY, HYDROGEOLOGY AND HYDROCHEMISTRY OF THE DAMASCUS PLAIN

The main hydrogeological units in the Damascus plain consist of proluvial-alluvial (western and central: 300 m thick) lacustrine deposits (eastern), and volcanic soil (southern and south-west). Many factors affect the chemical composition of groundwater and have resulted in its variation. For instance, groundwater in the western and central parts of the basin is found in alluvial-proluvial deposits (figure 2). Salinity is generally less than 0.5 g/L, seldom reaching the 1.0 g/L in the hydrocarbon-chlorine type. However, in the direction of groundwater flow from west to east, the salinity of the groundwater increases, and its composition changes from hydrocarbonic to chlorine-sulpheric. In the eastern parts of the plain, where lacustrine deposits are made up of mainly marly limestone, salinity sometimes increases to 5 g/L in the El-Oteiba and El-Haijaneh lake regions. At the western edge of the lacustrine deposits, there is a belt of groundwater of relatively low salinity (1 g/L), which is attributed to the recharge from the flow of the Barada River.

According to available data in 1986, the annual water demand in the Damascus plain was estimated at 590 mcm; of this amount, 110 mcm was available from surface water. The remaining 480 mcm was extracted from groundwater sources, which exceeded the recharge (400 mcm/year). This situation (of pumpage exceeding recharge) results in a drop in groundwater levels and change in the quality of water. The sources of groundwater recharge in the Damascus plain are surface water seepages from the Barada River and the Al-Awaj River, the waters of which originate in the AntiLebanon and the Hermon ridges. Additional local recharge comes from frequent floods from ephemeral streams and local rainfall. An isotopic analysis has been planned in order to study groundwater sources (recharge), occurrence and to define their location.

The Barada River catchment area (1,380 sq km) crosses the Damascus plain through a reach 40 km long. The discharge of the river, combined with the Barada and Feigha springs and branches at Damascus city varies, from 30 cm/sec (March and April) to 5 cm/sec (September and October). Average annual discharge is about 12 cm/sec. The river crosses the plain until it flows into El-Oteiba Lake; its slope does not exceed 2.5 m/km. Discharge of the river decreases along its course towards the east. It becomes almost dry during the summer months as it reaches its final destination at the Lake. The discharge of the river is conveyed in the plain through three groups of channels, which distribute the water for irrigation over the plain. Of these groups, the main group (seven channels) carries more than 6 cm/sec of annual discharge at the entrance point to the plain near Damascus city.

The Al-Awaj River (catchment area is 1,120 sq km) crosses the Damascus plain for a distance of 60 km before it reaches El-Haijaneh Lake. Most of the water is used for irrigation; therefore its flow, especially in summer, does not continue to El-Haijaneh Lake. Maximum and minimum discharge of this river are about 25 cm/sec and 0.1 cm/sec respectively. The average annual discharge is about 2.5 cm/sec.

waste and industrial waste dumps pollute groundwater and surface water resources. As water resources are depleted, and the amounts of wastewater disposed of increase, surface and groundwater resources are less able than before to absorb and neutralize these pollutants. The concerned Ministries are aware of the size of the pollution problems. Currently, a study is being completed on the assessment of water quality of the Orontes River, which includes measure to be taken to control pollution.

The most detrimental health effects of industrial pollution are often long-term, but for the Syrian Arab Republic, only a small amount of data is available on the impact of industry on water quality and health. Half of the country's largest and most important industries are located on the Orontes River, which also receives the domestic wastewater from Homs city. The Syrian Higher Institute for Advanced Science and Technology has just completed a study, the preliminary results of which have shown both bacterial and chemical contamination of sample points along the Orontes River and the Katina Lake (13). Other samples taken near a fertilizer plant discharging into the Orontes in January 1996 indicated an ammonia level of 221 mg/1, 185 times higher than safe levels .

Sewage treatment systems employing a variety of technologies are currently under construction in Damascus, Aleppo, Homs, Hama and Lattakia. Feasibility studies are being prepared for an additional seven cities. Several of these plants use activated sludge, requiring highly skilled personnel and continued access to appropriate equipment for successful operation. In addition, treatment processes have not taken industrial effluent into account; this could hinder the treatment process, which was what happened in Salamiyah. In Aleppo, the project plan provides for regulations on industrial discharge. In this project, effluent will also be used for artificial recharge of the aquifer. In most cases, the treated effluent is expected to be reused for agriculture. In this respect it is worth noting that the most dangerous contaminants—helminths causing worm-related diseases—cannot be removed by the activated sludge process of disinfection.

D. DAMASCUS: GENERAL FEATURES

Damascus is located in a basin with peculiar hydrological and hydrogeological characteristics. The Damascus basin includes surface water and groundwater which are being fully utilized to meet different needs such as drinking, domestic uses, irrigation and various industrial activities. The basin lies in the south-west of the Syrian Arab Republic (figure 1). It forms a natural hydrographic unit which includes the Damascus plain, and the mountainous region which feeds this basin with surface water and groundwater.

1. *Physical characteristics*

The basic physical features of Damascus are the plain and the mountains, which defined the linear urban development of Damascus. Damascus is characterized by varied geological and topographical features. The mountains extend in the northern and western regions of the basin while the plain lies in the central and eastern region. The mountains are the anti-Lebanon Chain (2,462 masl), the El-Harmoun mountain (2,814 masl) to the west, and the El-Kalamoun mountains (1516 masl) in the central and northern part of Damascus.

The Damascus plain (60 km long and 50 km wide) extends from the western flanks of the El-Kalamoun mountain in the west to the El-Outaibe and El-Heijaneh Lakes in the east (600 masl). It is of level topography; average height is 650 masl, with the lowest point in the El-Outaibe Lake (594 masl), which is considered the outlet for the Barada River, while El-Haijaneh Lake drains the Al-Awaj River. To the south and east of Damascus, the terrain is mainly basaltic outcrops.

B. WATER RESOURCES IN THE SYRIAN ARAB REPUBLIC

The Syrian Arab Republic is characterized by a Mediterranean climate. Annual average rainfall varies between 1,600 and 2,000 mm in mountainous zones close to the sea compared with 50 mm in desertic areas; which makes the country part of the region's arid and semi-arid zones. The calculated mean annual volume of rainfall is about 46 bcm. Average annual evaporation is estimated from 1.0 m to 2.8 m. The country's available water resources are estimated at about 10 bcm/year of which 4.4 bcm are surface water excluding the Euphrates and the Tigris about which no final agreement has yet been reached with Turkey; currently only 500 cm per second (15.76 bcm) is provided by Turkey from the Euphrates. The flow from perennial rivers and springs is shown in table 2. Table 3 depicts the surface and groundwater situation in the Syrian Arab Republic. The figures in table 3 are approximate but indicative, showing that the country's groundwater resources contribute about 35% of total available water resources. The main water user is agriculture. Other uses are domestic and to a lesser extent, industrial (2,3).

TABLE 2. MAIN RIVERS, BASINS AND SPRINGS IN THE SYRIAN ARAB REPUBLIC

River	Area of basin (Km^2)	Annual runoff in mcm	Source	Spring name	Area annual flow mcm/hr	Area source
Tigris	258 000	48 700	Taurus	Ras Al-Ain	40	Taurus
Euphrates	444 000	31 400	Armenia Plateau	Ein Arous	6.0	Armenia Plateau
Khabour	36 900	1 600	Taurus	Al-Hol	0.8	Taurus
Balikh	13 780	140	-	Ein Tannour	0.8	-
Sajou	2 372	135	-	Oarah	0.8	-
Barada	1 406	315	Mountain Zone	As Sin	6.0	Mountain Zone
Al-Awaj	515	100	Mountain Hermon	Sarout	1.0	Mount Hermon
Queik	4 214	95	Taurus Mountain	Feijeh	8.13	Taurus Mountain
Sinn	-	315	Coastal Highlands	Munire	0.4	Coastal Highlands
Kebir Shamali	1 09	210	-	Mzeireb	1.4	-
Orontes	15 540	1 275	Al Beqaa & Gabb	Baniyas	1.7	Al Beqaa & Gabb
Afrine	2 680	230	Mount. Kerdagh	Bared	2.5	Mount Kerdagh
Kebir Janoubi	981	190	Coastal Highlands			Coastal Highlands
Yarmouk	9 242	440	Yarmouk Basin			Yarmouk Basin

Source: *Optimization of Water in Agriculture, Proceedings of the Regional Seminar, Amman, 21st - 24th November 1994*, organized jointly by the Commission of the European Communities and the French Ministry of Foreign Affairs in cooperation with the Jordanian Ministry of Water and Irrigation.

The Syrian Arab Republic mainly depends on surface water, and in certain regions, on groundwater. The water quality is generally good, except for some regions where it could be described as fair.

In the Syrian steppe, there are two principal types of groundwater with low salinity: (a) fossil groundwater in the Karstic carbonate aquifer; and (b) groundwater related to the present indirect recharge from infiltration of wadi run-off. The water quality of some sources, especially rivers, is suffering from pollution problems arising from the disposal of industrial and other wastewater. The decrease of inflow of the Euphrates River, owing to the construction of the huge Attaturk dam in Turkey and the networks of dams and canals, is causing serious concern because of its effect on the quality of the water in the river basins through the Syrian Arab Republic. The degradation of water quality caused by the infiltration of saline water into the fresh water aquifers is occurring along the Syrian coast, particularly in the areas that depend on surface aquifers. Some of the country's rivers have become dumping sites into which industries discharge waste. The Orontes River, for instance, is being polluted by wastes discharged by certain industries (petroleum refinery and phosphate plant).

4. *Pollution from domestic, municipal, and agricultural wastewater*

Although in principle water supply and sanitary services should be provided together, the tendency in most parts of the world is to target limited financial resources to water supply systems, without a corresponding increase in funding for wastewater treatment. Reports estimate that 45% of the Middle East and Northern Africa (MENA) region's urban population had access to sewerage systems (9). Sewerage systems in many urban areas are overloaded and often lead directly to rivers, lakes, open land areas or the sea.

Wastewater treatment plants, where existent, often cannot function owing to lack of funds, inadequate design or lack of technical personnel. Comprehensive data on wastewater treatment are limited, but the World Bank gives a few examples of wastewater treatment systems in some urban areas. In Egypt, for example, there are only four medium-sized cities with functioning waste stabilization ponds. Approximately 70% of the populations in Cairo and Alexandria are covered by sewage treatment works, from which some effluent will be used for irrigation. Yemen, with relatively low coverage of sewage treatment in 1990, had 10 sewerage and sewage treatment projects under preparation at the time, almost all of them waste stabilization ponds. Jordan had 14 operational plants. In those areas with activated sludge treatment plants, there is often no provision for disposal of the sludge.

Much attention has been given in recent years to wastewater reuse in agriculture. In general, only in a very few countries are there strict, enforced regulations on the use of domestic wastewater for irrigation. Intensive and direct reuse without treatment is the norm in almost all countries, with unsupervised use in many countries in the region.

Urban populations not served by sewerage networks either have household dry pit latrines or septic tanks. In Gaza, leakage from cesspits into the groundwater table has been shown to cause higher nitrate content than in agricultural areas (10). Cesspits and septic tanks are emptied periodically by vacuum tankers, which in most cases also dump the waste indiscriminately in open areas or the edge of seas or rivers.

Uncontrolled, widespread use of agro-chemicals on both irrigated and rain-fed agricultural areas can have far-reaching health effects, which to date have not been quantified or fully studied in the ESCWA region.

5. *Pollution from industrial solid and liquid waste*

Although a relatively small user of water, industrial pollution potentially has worse long-term effects than other sources. Because the health risks are not immediately evident, and industrial water use is low, industrial pollution has only recently received attention in water resources management. There are also extremely limited data available on types and levels of pollution, although most sources agree that industrial wastes are now significant pollutants in the region (11). Surveys confirm that treatment of industrial effluent is generally unsatisfactory throughout the region (7).

Owing to the great variety of composition and volume of industrial waste, and the wide variations in the effluent even from the same plant, skilled operation is needed to provide an acceptable effluent. Treatment is usually expensive, and therefore also requires strict regulations forcing industry to comply with the established standards. In Egypt, for example, about 300 mcm of untreated industrial wastes are discharged into the Nile every year. In addition, agricultural drainage systems receive large quantities of industrial wastes and sewage. In Jordan, most industrial wastes are discharged in the Seil El-Zarqa Basin, which pollutes the King Talal Dam Lake, the main irrigation source of the Jordan Valley. In Alexandria,

TABLE 1. URBAN POPULATION IN ESCWA MEMBER COUNTRIES AND MAJOR CITIES

Country/area	Level of urbanization (percentage of total population in urban settlements)			Urban population (thousands)			Annual growth rate (percentage)		Estimates and projection (thousands)			Annual growth rate (percentage)		
	1975	2000	2025	1975	2000	2025	1975/ 2000	2000/ 2025	1975	2000	2015	1975/ 1985	1995/ 2005	2005/ 2015
Egypt	43.45	46.36	62.20	16877	32054	60519	2.57	2.54						
Alexandria									2241	3998	5546	2.35	2.23	2.16
Cairo									6079	10731	14494	2.35	2.09	1.97
Bahrain	79.23	92.22	95.85	215	584	884	4.00	1.66						
Jordan	55.31	74.48	83.95	1438	4772	10107	4.8	3.00						
Amman									500	1458	2327	4.47	3.89	2.84
Iraq	61.39	77.08	85.42	6765	18308	36435	3.98	2.75						
Baghdad							•		2747	5068	7324	2.93	2.58	2.38
Kuwait		97.65	98.56	844	1776	2765	2.98	1.77						
Kuwait city	83.81								682	1198	1572	3.23	2.04	1.63
Lebanon	66.83	89.50	93.88	1849	2943	4154	1.86	1.38						
Oman	6.28	15.67	32.54	53	412	1983	8.20	6.29						
Gaza Strip (Palestine)	87.00	94.90	96.61	339	830	1357	3.58	1.97						
Qatar	82.94	92.56	95.38	142	560	762	5.49	1.23						
Saudi Arabia	58.70	81.80	88.20	4257	17388	37618	5.63	3.09						
Riyadh									705	3225	5117	6.87	4.06	2.81
Jeddah									584	2076	2771	4.89	3.47	2.89
Syrian Arab Republic	45.06	54.87	69.57	3352	9508	23311	4.17	3.59						
Damascus									1122	2408	4047	3.45	3.38	3.41
Aleppo									879	2241	3824	3.82	3.79	3.44
United Arab Emirates	65.40	86.23	91.29	330	1817	2700	6.82	1.58						
Yemen	16.4	38.42	58.42	1147	6550	19647	6.97	4.40						

Source: United Nations Centre for Human Settlements (Habitat), *Global Report on Human Settlements 1996*.

ABBREVIATIONS

ACAD	Arab Centre for the Study of Arid Zones and Dry Lands
amsl	above mean sea level
bcm	billion cubic meters
BOD	biological oxygen demand
BWRO	brackish water reverse osmosis
C	centigrade
$CaCO_2$	calcium carbonate
C1/L	chlorine/litre
cm/sec	cubic metre/second
CO_2	carbon dioxide
COD	chemical oxygen demand
Cu.m	cubic metres
DO	dissolved oxygen
ESCWA	Economic and Social Commission for Western Asia
FAO	Food and Agriculture Organization of the United Nations
gpd	gallons per day
g/L	gallons per litre
km	kilometre(s)
l/d	litre per day
lpcd	litres per capita per day
LS	Syrian pounds
masl	metres above sea level
m^3/h	cubmic metres per hour
m/km	meter per kilometer (slope)
mcm	million cubic metres
mcm/d	million cubic metres per day
mcm/yr	million cubic metres per year
mgd	million gallons per day
mg/l	milligrams per litre
ml/m^3	millilitres per cubic metre
mm	millimetre
NGO	non-governmental organization
ppb	parts per billion
ppm	parts per million; in this report, it is considered to be equivalent to milligrams per litre (mg/l)
ppt	parts per thousand
Rl	rapid infiltration
SANAX	strong acid/sodium ion exchange
Sp.Gr.	specific gravity
SR	slow rate
SS	suspended solids
SWRO	sea water reverse osmosis
TDS	total dissolved solids
THMs	trihalomethanes
TSE	treated sewage effluent
TSS	total suspended solids
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme

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