

# **A NATIONWIDE POLLUTION ABATEMENT PROGRAM FOR LEBANON, USING GIS ANALYSIS**

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## **ABSTRACT**

Over the past half century, Lebanon has experienced rapid population growth, accompanied, in recent decades, by mass migration to environmentally sensitive upland areas. Many communities have laid sewer lines, but the country has no effective systems for treatment or disposal of wastewater. The future wellbeing of the entire national community, including its tourist industry, is endangered by the unrestricted discharge of raw sewage into its vitally important groundwater reservoirs and across its Mediterranean beaches.

To address this problem, a national wastewater management program has been developed by updating and modifying an earlier master plan. A Geographic Information System (GIS) approach was introduced to record the characterization, analyze the needs, and generate conceptual plans and programs to serve more than 1,600 communities located in 68 watershed basins.

Emphasis is placed on the importance of establishing a permanent institutional structure to enforce environmental health safeguards and provide effective monitoring of operation and maintenance as collection, treatment, and disposal facilities come into service.

Preconstruction activities for priority areas are now underway.

## **KEY WORDS**

Lebanon, GIS, Wastewater, Pollution Abatement

## **INTRODUCTION**

From time immemorial, Lebanon's narrow coastal plain has ranked among the great meeting places of world civilizations. For more than two millennia, Phoenician maritime supremacy extended throughout the Mediterranean basin and beyond, exercised from its major seaports of Saida (Sidon) and Sour (Tyre), and others, including Berytus (Beirut) and Byblos (Jbail). Conquest by Alexander the Great in 333BC was followed by twenty-two centuries of dominance by a succession of occupying regimes, lasting until the advent of independence after World War II. Post-war prosperity brought increased mobility and dispersal of many permanent and seasonal homes to upland areas that had hitherto been sparsely populated. In a region dependent almost exclusively on underground sources for its potable water supplies, this trend exacerbated contamination and public health problems already prevalent along the coast. Concurrently, many younger people have crowded into major cities, particularly Beirut and Tripoli, seeking gainful employment in industry or commerce and, incidentally, contributing to the degradation of urban and shoreline conditions. The pollution abatement program described in this paper is in response to these problems.

## THE LAND AND ITS PEOPLE

The Republic of Lebanon occupies about 225 km. (140 mi.) along the eastern coast of the Mediterranean Sea, and covers a land area of about 10,450 sq. km. (4,030 sq. mi.), roughly rectangular in shape. Its principal physical features, shown in Figure 1, are the Mount Lebanon and Anti-Lebanon ranges, more than 2,500 m. (8,200 ft.) high at peaks, the broad Bekaa Valley between the ranges, and a narrow coastal plain. The Bekaa drains southward to the Litani River, which cuts through to the west into the Mediterranean and is the country's only major perennial watercourse. Other rivers, including El Bared, Abu Ali, Ibrahim, El Kalb, Awali, and

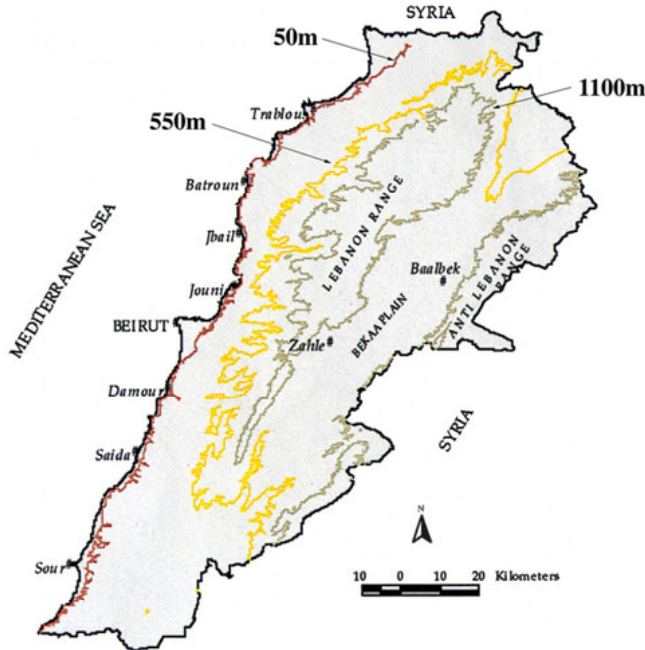


Figure 1. Topographic Map of Lebanon

Zahrani discharge year-round from some of the 50 western watersheds to the Mediterranean. The upper basins of the Orontes and Hasbani drain into neighboring countries.

Off much of the coastline, the seabed dips rapidly to depths exceeding 100 m. (328 ft.). The littoral current along this almost tideless coast is predominantly northward. Since Phoenician times, repeated efforts have been made to capture, for use on land, the copious flows from offshore fresh water springs near Chekka, north of Batroun.

The geologic structure of Lebanon is heavily faulted and contorted. Deep beds of karstic limestone and dolomite, covering over two thirds of its area,

contain the nation's most vital natural resource, its groundwater supply. This supply is replenished annually by winter rain and snow.

Over five millennia of history have bequeathed Lebanon with a people of wide ethnic and sectarian diversity, constantly enriched by independence-loving people seeking refuge from oppressive conditions in other lands. Since the time of Alexander, conquerors have generally governed Lebanon with a light hand, and the various ethnic groups have enjoyed freedom to settle, largely in segregated enclaves, some coastal, some mountain, and some in the Bekaa. The idea of national identity with common goals and a central government's responsibility for the security and wellbeing of all the people has scarcely existed. Not surprisingly, when independence came in 1943, a high priority was not placed on the creation of such public service instruments of national government as an environmental management authority. In consequence, provision of public services was initially fragmented, responding only to perceived local needs. However, realization of the need to visualize, plan, and finance such vital concerns as environmental management is now gaining ground.

No census has been taken since 1932, so the data are somewhat untrustworthy, but it seems likely that from the 1932 count of 785,770 to independence day, eleven years later, the population almost doubled. There was considerable new settlement near the coast, with small communities and tourist resorts dotting the uplands, while the town of Zahle served as the market center for villages in the fertile Bekaa. Following independence, Lebanon was ideally placed to take advantage of burgeoning activity in

Middle East oil fields. Broken only by an outbreak of civil unrest in 1958, its service economy expanded rapidly, largely in trade, finance, and tourist sectors. Prosperity brought a surge of private building development, both around existing towns and into the mountains, though the importance of environmentally sound wastewater disposal was apparently not considered at the time. By 1970, the population had grown to an estimated 2.5 million.

Large segments of the populace did not share in the benefits accruing from the business boom, however, and mounting regional and factional dissensions led in 1975 to the violent shattering of the “Lebanese Miracle.” The ensuing 15 years of devastation caused mass displacement of population, largely to environmentally sensitive mountain areas, where refugees found shelter, often in existing communities which became grossly overcrowded. The eventual abatement of open hostilities brought growing realization of the critical shortage of livable housing and lack of workable public utilities. The 1994 national population was estimated to be about 3.3 million. Figure 2 highlights the surge to the mountains.

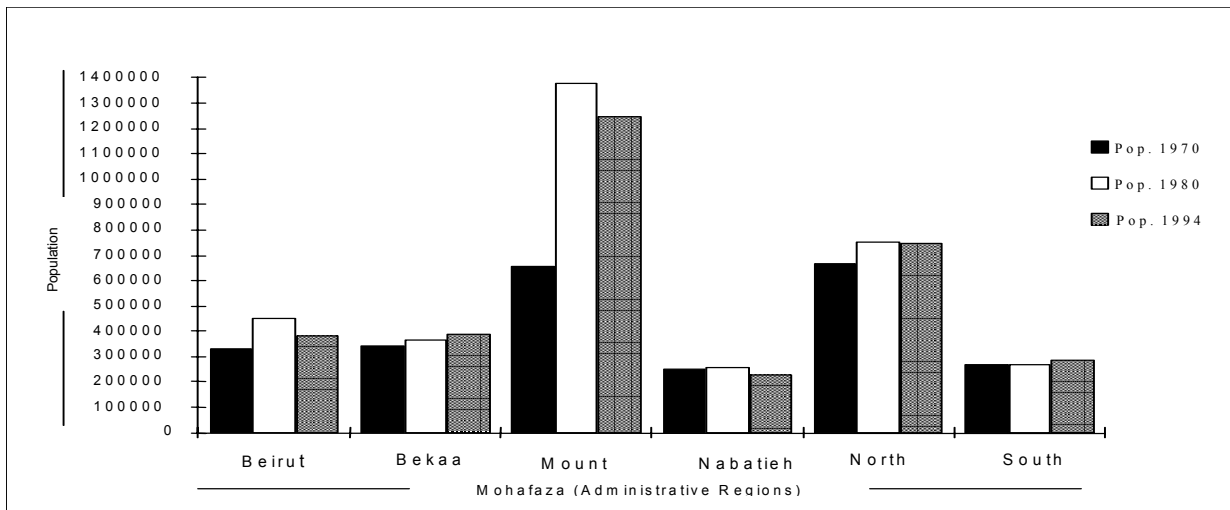


Figure 2 - Population Growth by Mohafaza, 1970 - 1994

### THE WATER POLLUTION PROBLEM

Before the onset of war, 121 communities had sewerage systems, some city-wide and some local. Over the years, a very limited number of small treatment facilities, applying various process trains, had been set up, but not one remained in operational condition. Post-war surveys revealed that most collection systems were clogged or otherwise unserviceable. In unsewered areas, sample surveys showed most on-lot disposal systems to be ineffective. Consequently, in upland areas, raw sewage percolated through the fissured and cavernous rock into an aquifer. This condition has been exacerbated by post-war developments.

Combined storm-sanitary drainage systems serving coastal cities and towns discharge untreated waste close inshore or across beaches. Although several marine outfall

pipelines have been constructed, none appear to be in effective service. Pollution of groundwater in this region has been increased by seawater intrusion, caused by over-pumping of boreholes to provide urban, industrial, and agricultural supplies. Fertilizers, pesticides and, in some localities, industrial discharges have further complicated the problem. The trend has been aggravated by the postwar revival of

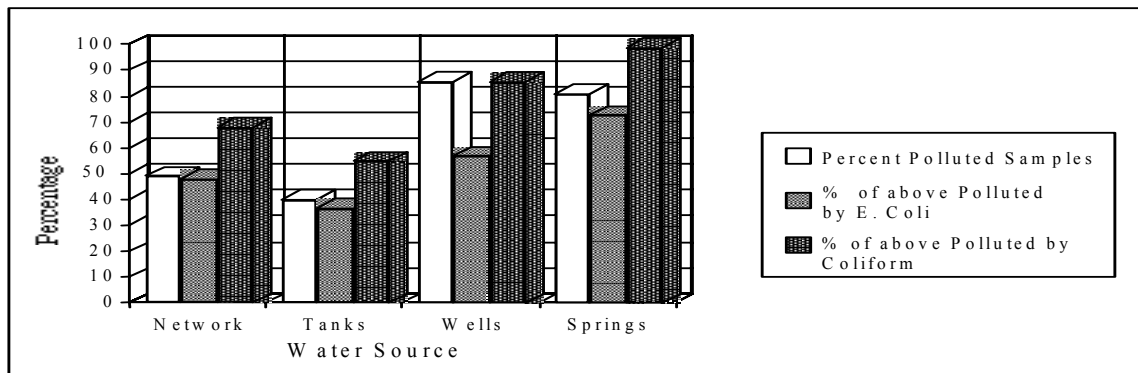


Figure 3 - Pollution in Drinking Water Samples, 1994

### Lebanese industry.

Early in the war, the United Nations Development Program (UNDP) responded to a Government of Lebanon request by initiating a nationwide field survey of waste disposal problems and formulation of a remedial action plan. Prepared in 1980-82 under the direction of the World Health Organization (WHO), the National Waste Master Plan (NWMP82) provided a solid foundation for reappraisal and modification in response to postwar conditions. This led to preparation, in 1994-5, of the Lebanon Staged Wastewater Program (LSWWP).

Justification for the large investment needed to implement a nationwide program rests mainly upon public recognition of the adverse impact, both financial and human, of prevailing conditions on community health, and the prospective growth of risks associated with failure to take timely and effective action.

Although archival evidence linking groundwater pollution to drinking water quality and community health in Lebanon is sparse, reports of special studies demonstrate a clear connection and trend.

NWMP82 report cited Central Public Health Laboratory analyses of drinking water samples collected in 1980-81, which showed that "...for locations outside Beirut, 30% of the samples had coliform bacteria present, with no significant seasonal variation. Beirut water followed a seasonal variation, with coliforms detected in only 5% of winter samples, but up to 20% of the samples in October and November. Of all the samples from wells and springs, 40% had coliforms present."

By comparison, tests conducted by the National Central Laboratory on 720 samples of drinking water, collected nationwide in 1994, showed 440 (67%) had coliform bacteria. These findings are illustrated in Figure 3. Extensive field and laboratory tests conducted by Dr. Al-Jurdi of the American University of Beirut (AUB) had shown the incidence of pollution in wells and springs to be higher in 1994 than they had been in 1990, but lower in storage tanks and distribution networks, a clear sign of deterioration at critical locations in the intervening years, partially offset by improving water treatment practices.

Further evidence of environmental degradation by discharge of untreated wastewater was provided by a Ministry of the Environment survey of coastal water quality, conducted in 1993. The results are summarized in Table 1.

**Table 1 – Bacteria Count Along the Lebanese Coastline, 1993**

Test Location	Test Location in Relation to Service Area	Bacterial Count in 100 milliliters
Rass El-Saaker	North of Sidon (or Saida)	35
El-Bahsas	South of Tripoli	1100
Jbail	Jbail	1100
Dbayie	North of Beirut	93
Ramleh El-Baydah	South of Beirut	11000
Ramleh El-Baydah	South of Beirut	Cholera Organisms

Regarding the linkage between polluted drinking water and public health, NWMP82 report commented on the dearth of information on reportable diseases, but quoted a 1980 AUB survey as tracing records of 1,510 cases of typhoid, 387 of viral hepatitis, and 204 of shigellosis occurring during 1979. One informed, though unofficial report suggested that the incidence of gastroenteritis and amoebic dysentery among the general population might be as high as 80%. Although the circumstances attending individual cases of these maladies vary, they are all associated either directly with consumption of polluted water, or indirectly through lack of cleanliness or consumption of fruits and vegetables irrigated or washed in polluted water.

In 1995, the Epidemiological Surveillance Unit (ESU) of the Ministry of Public Health issued its first newsletter (EpiNews) on reportable disease statistics for Lebanon. Its March 1996 issue indicated that, by the end of 1995, only 54 of the country's 148 public and private hospitals were submitting reports. Health care centers and laboratories had started to report. Although the number of cases summarized in Table 2 is obviously not complete, the monitoring routine appears to be gaining strength.

No basis appears to be available for determining the number of cases that did not involve professional intervention, or the number of persons who carried and spread the infections without being seriously incapacitated. These may be numerous.

**Table 2 - Reported Incidence of Diseases Attributable to Pollution of Drinking Water, 1995-1997**

Reportable Disease	Jan- June 1995	July- Dec 1995	1995 Full Year	Jan- June 1996	July- Dec 1996	1996 Full Year	Jan- June 1997	July- Dec 1997	1997 Full Year
Brucellosis	53	188	241	129	170	299	155	161	316
Dysentery	92	532	624	487	610	1097	286	340	626
Hepatitis (all types)	78	323	401	267	312	579	374	312	686
Typhoid/Paratyphoid	565	714	1279	335	536	871	539	314	853

As stated in EpiNews, March 1996 issue, ".... inaccurate and incomplete data .... can lead to improper planning .... And most definitely will lead to a tremendous increase in health care costs on the government and a burden on the public ...."

## WASTEWATER FACILITIES PLANNING

The nature, extent, and cost of wastewater management facilities needed in a land that is not highly industrialized depend mainly on the projected sizes and distribution of population groups, the terrain in which they dwell, and available disposal options. The presence of usable existing systems may be a factor.

In the absence of official population counts, several indirect methods were applied to derive projections for LSWWP. The most dependable sources of information were

found to be the electricity supply undertakings, which maintained multi-year records of the number of domestic and business subscribers in each individual service district. Other sources provided corroborative input and data on typical household sizes. Making allowances for business consumption, tourist needs, and seasonal migrations to resort areas, an “equivalent population basis” was derived for each community and projected at 5-year intervals to the year 2050. These projections are summarized regionally to year 2020 in Figure 4. Of particular note is the anticipated rapid growth for the Mount Lebanon region. For initial stage planning, 2015 AD was adopted as an appropriate “design year.”

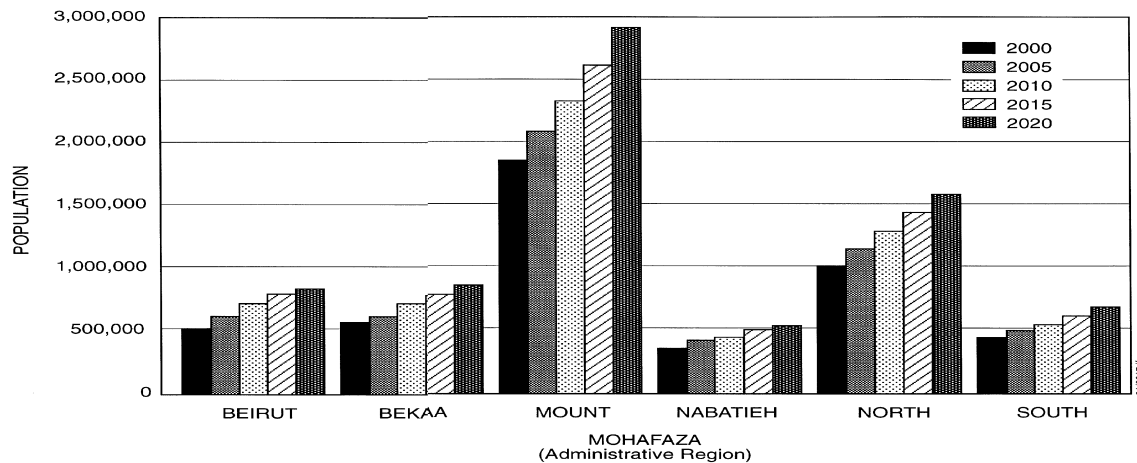


Figure 4. Design Population Growth by Mohafaza, 2000-2020

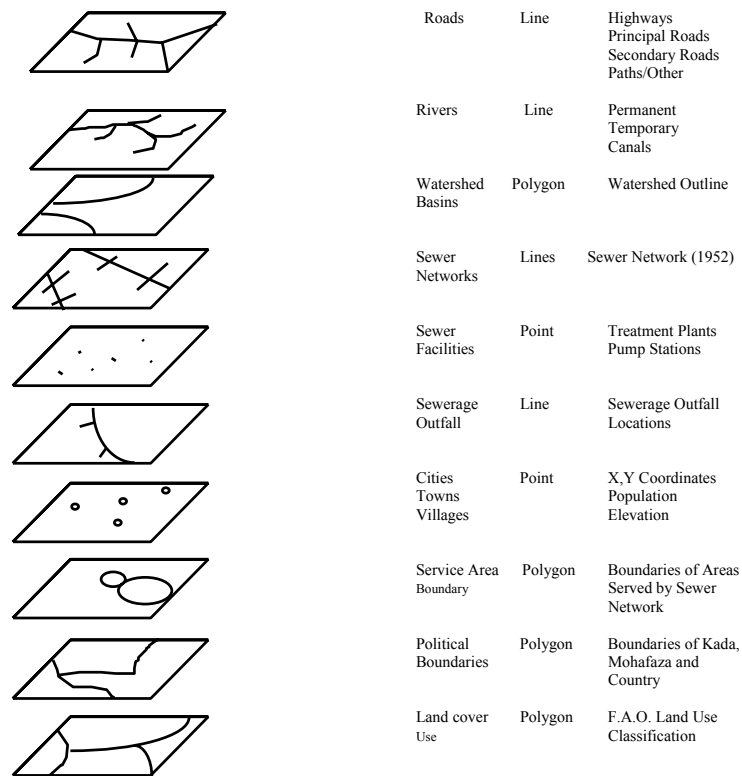
Design criteria developed for NWMP82 were reviewed in the light of subsequent advances in environmental knowledge, wastewater and materials technology, construction techniques, and international standards. Guidelines were established for the planning and design of wastewater collection, conveyance, treatment, and disposal facilities appropriate to each type of location in Lebanon.

With the aid of GIS technology, an analysis was made of each of the 68 watershed basins in the country containing a total of more than 1600 communities (see Figure 5). ARC/INFO GIS software was used to integrate, store and manipulate spatial data by converting maps and other spatially related input to digital format and combining them in a single geo-referenced file. The forms of spatial data collected included: population data for all the cities, towns, and villages of Lebanon, administrative boundaries, permanent and seasonal rivers, all classifications of roads, watershed areas, land cover/use classifications and the sewer systems proposed in NWMP82.

The data file was used to facilitate the spatial analytical process. Examples of this type of analysis included: (1) setting a minimum population level for the villages to be included in the study and recording the villages which do not meet these requirements, (2) determining the total population of these cities, towns and villages which fall within a single watershed area, (3) generating three dimensional models of selected areas to obtain a better understanding of the terrain around each individual site, (4) identifying towns which fall within a certain distance from an existing or

proposed sewer trunk line, and determining the feasibility of connecting them to these lines, (5) proposing a waste disposal method based on the location of a town, along the coastline or in the mountain area, (6) proposing locations of sewer lines, using the spatial analytical capabilities of GIS to make sure these proposed lines did not encounter major obstacles. Finally, the GIS was used to generate maps of different scales to emphasize various aspects of the program.

Figure 5. GIS Layers for Sewer Systems Analysis



## Conclusions

Examined in conjunction with other pertinent information, the analysis pointed to several basic conclusions:

1. Improved or extended sewer service is needed in and around coastal cities and along partly built-up corridors leading to coastal and upland settlements too numerous to be served individually by treatment and disposal systems.
2. Past experience in Lebanon has demonstrated that most sewer systems devised to serve individual communities have lacked proper means of disposal and have not remained serviceable, but have created pollution problems for settlements downstream.
3. In the agricultural Bekaa region, public health is adversely affected by lack of effective sanitation, even for large communities, and by lack of clean water for irrigating and washing produce.
4. Some important upland communities, including tourist resorts, are too remote to be served by regional systems. Hard winters and wide seasonal fluctuations of population are the rule. Special treatment and disposal design criteria are indicated.
5. Almost a quarter of the country's present population resides in isolation or in communities too small to be served by sewage collection systems. Dry sanitation or on-lot waterborne disposal methods prevail. Most of the existing waterborne disposal systems are environmentally unsound. This segment of the population is not expected to increase.
6. Industrial establishments are concentrated mainly around larger towns, and their discharges constitute about 10% of total wastewater flows. They have continually changing characteristics. Segregation at source of all process waste streams should be mandatory, to enable safe and efficient disposal methods to be determined.
7. Acquisition of suitable land for pumping, treatment, and disposal facilities is a difficult and costly process, requiring high priority, expert action. This is particularly the case along the coast, and points to the need for a small number of large treatment and outfall systems rather than many small ones.
8. Of the major planning objectives — (a) abatement of aquifer and shoreline pollution on a broad scale, (b) expansion of service to rapidly growing areas, and (c) effective sanitation for overcrowded and poorly served urban areas, each vying for limited natural resources — sound public health and security policy would accord priority to objective C, effective sanitation.
9. Given the modest expanse, population base, and resources of Lebanon, and the desirability of maintaining good relations with international agencies on LSWWP and related matters, it would be most efficient to manage facilities planning, design, specification (including standardization), and major procurement on a unified national basis. Apart from regional facilities, operation and maintenance of most installations would best be delegated to competent local authorities.

10. Essential ingredients for sustainable progress are broad public awareness of the critical nature of the problem of environmental degradation, and participation by the national community, including nongovernmental organizations, in the development of remedies.

## **Planning Recommendations**

From the above considerations, LSWWP derived the following broad planning recommendations:

1. For major parts of watershed basins on the west flank of the Mount Lebanon range, the most effective and environmentally sound procedure will be to convey wastewater by pipeline to the coast for treatment and offshore disposal.
2. Flows from upland regions and from coastal centers of population will best be collected and conveyed to a major coastal treatment facility with a marine outfall pipeline. The number of such facilities should be minimal, subject to practical constraints. At the initial stage of development, a preliminary level of treatment is recommended, but with land acquired for future expansion and upgrade to secondary treatment, when needed to satisfy international coastal water standards. Outfalls should be sized to convey projected long-term flows.

A typical regional wastewater system with coastal treatment plant and marine outfall is illustrated at Figure 6. In this plan, growth of the service area would radiate outward in stages from Lebanon's second city, Tripoli, after treatment and disposal installations have demonstrably proved themselves. Proof of successful operation is needed to reassure skeptical downstream populations.

Conveyance, treatment and effluent pumping facilities have recently been connected to the 2.6 km marine outfall constructed in 1982 in the high-priority South Beirut region, and the system is in service.

For the region around the southern city of Sour (Tyre), detailed studies, conducted since the issue of LSWWP, have shown that, by providing a full secondary level of treatment, effluent could be applied to irrigate an extensive area under bananas and citrus fruits. A marine outfall will provide back-up.

3. Where alleviation of seawater intrusion into a coastal aquifer becomes necessary (e.g., to maintain agricultural production), judicious injection of effluent from a secondary treatment process should be considered. The use of processed sludge on farmland should be subject to strict monitoring for toxic or pathogenic content.
4. Where combined storm-sanitary drainage systems exist in coastal towns (usually with multiple short outfalls off-shore), it is recommended that sanitary flows be diverted into separate sewer systems.

5. In the broad Bekaa valley, regional systems are proposed for the rapidly expanding commercial and administrative capital, Zahle, for the archeologically renowned resort of Baalbeck and numerous surrounding agricultural settlements, and for communities in the intensively cultivated region around and downstream of Lake Qaraoun, further south.
6. As a general guideline for implementation of LSWWP, prior to 2015, in communities not covered by regional systems, the following criteria are recommended:
  - For rural settlements and other small isolated communities of fewer than 1,000 population, on-lot disposal systems should be used, except where sewer service is imperative for environmental protection. These communities number about 1,200 and are home to approximately 23% of Lebanon's total population.
  - For medium (1,000 to 10,000 population) and larger towns, sewerage should be provided. Wherever feasible, treatment and disposal facilities should serve a group of communities.
7. On-lot disposal systems should be upgraded where needed to conform to national standards appropriate to site subsoil characteristics. For this, a need for government support and incentives is to be expected. Environmentally sound means should be provided, and their use enforced, for disposal of septage (septic tank sludge), where possible by stabilization and sluicing into sewer systems through septage receiving stations.
8. Prior to process selection for inland treatment plants, a pilot demonstration plant (or plants), incorporating an array of processes, and an operators' training center should be placed in service. Zahle is the favored location for these facilities, which should be under central administrative control.
9. To the fullest extent possible, designs of comparable facilities should be standardized, and uniformity should be sought in equipment selection. The aim should be to save costs and promote efficiency in operation, maintenance, and storekeeping.
10. The institutional structure for wastewater management should include a branch dedicated to (a) lively awareness of existing and emerging industrial wastes, their characteristics and methods of handling, (b) technical services to industry regarding safe and acceptable disposal procedures, and (c) coordination of waste monitoring and enforcement of exclusionary rules promulgated by higher authorities.

## Required Facilities

An inventory of required facilities, recommended in LSWWP for inclusion in the capital works program, has been derived from the basin analysis and related considerations, and is presented in Table 3. Figure 7 shows the locations of the proposed regional and community service areas.

**Table 3 - Proposed Wastewater Facilities**

Number	Required Wastewater Facilities
5	Regional collection, conveyance, and treatment systems
4	Sea outfalls for the regional systems
1	Rehabilitate and extend regional system and sea outfall and add treatment
2	Coastal subregional collection and treatment systems with outfalls
3	Inland regional collection, conveyance, and treatment systems
4	Inland subregional collection, conveyance, and treatment systems
37	Single inland community collection and treatment systems
1	Pilot scale demonstration treatment facility
1	Operations and maintenance training center

## DESIGN CONSIDERATIONS

The design program calls for action on a wide variety of proposed installations in a wide variety of environments. Numerous entities are involved in design and related services. It is important that individual ingenuity be tempered, though not extinguished, by recognition of the inescapable need to comply with a degree of standardization and uniformity in design and evaluation practices.

## Collection And Conveyance Systems

Lebanon's rugged terrain presents a special challenge to the routing of gravity-flow sewer lines. In numerous instances, feasibility and cost determinations will need to be made of the choice between deep trench excavation, possibly in rock, divergence from public rights-of-way across privately owned land, or installation and maintenance of pumps. Although each case should be determined on its merits, experience may indicate need for a standard evaluation process, as well as for uniformity and speed in procurement of needed easements.

## Treatment Systems

Local terrain and climatic extremes will play a significant role in the selection of process trains for inland treatment facilities. Leading design considerations will include:

- Sewage flow volumes, characteristics, and seasonal variations.
- Effluent standards, particularly site-specific constraints on pathogens and oxygen demand.
- Size, topography, and geology of available treatment sites.
- Distance of sites from projected service areas. (Costs of trunk sewers).
- Proximity of sites to habitations and to access ways.
- Availability of a reliable off-site power source.
- Options for disposal of processed sludge.
- Potential demand for acceptance of septage for processing.
- Simplicity and economy of operation and maintenance.
- Overall annual per capita cost of treatment facility and trunk sewers.

The costliest and most critical components of LSWWP are the coastal treatment plants, with their influent and effluent pump stations, marine outfalls, and residual solids disposal facilities. Current

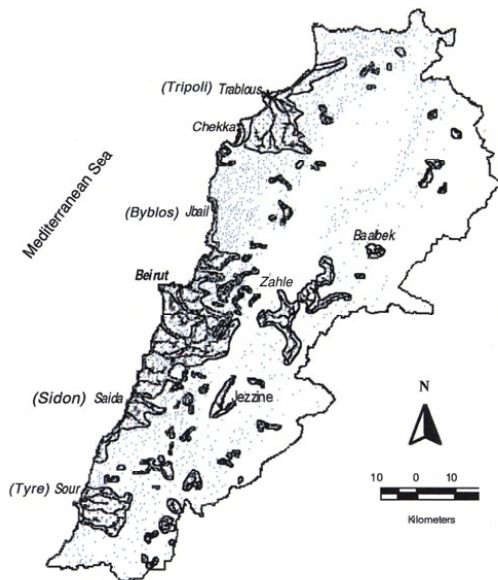


Figure 7. Locations of Proposed Regional and Community Service Areas

Stage 1 policy is to provide only preliminary treatment (screening and grit removal), on the assumption that outfalls will be designed to diffuse waste plumes adequately to satisfy Mediterranean Convention Standards for dilution and dispersion of pollutants and die-off of pathogens. Little is known of the dispersion/die-off characteristics of surface currents along the Lebanese coast, or of the possible impact of offshore waste discharges on beaches and fishing grounds. Oceanographic investigations and offshore geotechnical surveys, being highly specialized and requiring costly mobilization and analysis, would advantageously be conducted as a unified operation covering all potential outfall sites along the Lebanese coastline. In addition to site-specific investigations, opportunity should be taken to make a meticulous, year-round monitoring survey and model analysis of the performance of South Beirut outfall under steady, continuous discharge conditions. Review of the findings may influence policy and design decisions for subsequent coastal installations.

## MANAGEMENT PLANNING

LSWWP addresses engineering and environment, construction and costs, operation and maintenance, all in the context of local needs and resources. Implementation should not present insurmountable technological difficulties. Lebanon possesses a substantial cadre of professional expertise, ready access to outside support, and considerable practical experience, throughout the Middle East and beyond, in execution of comparable projects.

Allowing for price escalation at an average annual rate of 5%, but excluding provision for financing of loans, the capital investment for LSWWP, assuming completion by year 2006, was estimated to be approximately \$3.05 billion. Annual costs for operation, maintenance, and administration would increase as systems come into

service, and could amount to some 3% to 5% of productive capital costs. This level of outlays will represent a significant element in national budgets, in perpetuity.

Since wastewater management will involve such a sustained and onerous commitment of public resources, exercised either directly or by contract to private entities, a prime prerequisite for successful funding and implementation of the program is national and local political and fiscal stability, together with creation of a competent institutional structure, able to maintain, in the long term, the confidence of government, citizens, and outside investors.

## **PROGRAM IMPLEMENTATION**

Progress has been made since 1995 toward integration and strengthening of diverse national efforts designed to improve environmental safeguards, including specifically water resource and wastewater management. Public awareness of, and support for, this vital need has yet to be fully awakened.

Progress is also being made, partly with support from international funding and technical assistance agencies, on detailed planning and design of improved and extended wastewater systems for Beirut and other coastal cities and their environs. Studies are also proceeding for some inland urban centers, including Zahle in the heart of the fertile Bekaa Valley.

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