1 Set.

Sewerage Board of Pafos

Specific Study on the Main Environmental Impacts of the Sewerage and Drainage System

FINAL REPORT

Louis Berger S.A. / M. Jordanou & Associates

in Co-operation with:

Proplan Ltd

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Contents

1.0 INTRODUCTION

1.1 History of the assignment

This specialized assignment is the result of the discussion held at the Technical Committee for the Evaluation of Environmental Impact Assessments on the 3rd of March 1997. The full text of the minutes of the meeting are given in Appendix I.

The questions raised at that meeting are summarized below:

- Air pollution and the need for a dispersion model
- Pumping station (PS) with emergency outfall to the sea
- Central sea outfall in case of emergency
- System for data collection on marine ecology
- Treated wastewater (TWW) reuse including the use for ground water recharge
- Supply of TWW to hotels
- Disposal of sludge
- The urban storm water drainage and its impact on natural channels
- Position of sewage ponds.

Following this meeting the Ministerial Committee, on the 28th November 1997, addressed a letter (Appendix II) through the Ministry of the Interior to the Mayor of Pafos, President of the Pafos Sewerage Board (SBP) which inter alia demands the preparation of a detailed Environmental Impact Assesment for the plot of land designated for the Sewage Treatment Plant (STP). The EIA should take into account the technology proposed while the STP should be constructed to such standards so as to cause the least possible nuisance and should specifically include the following:

- The preliminary treatment section of the STP to be fully covered
- There should be a mechanized sludge treatment unit
- There must be facilities for the reception and treatment of septage.

In June 1998 Louis Burger SA, through their local associate Michael Jordanou and Associates (MJA) received an assignment from SBP to proceed with the required studies. Mr E. Malikides of the SBP prepared the Terms of Reference (TOR) for this assignment which PROPLAN Ltd has been asked to work to as an associate to MJA. The draft of the terms of reference prepared by SBP was discussed and finalized during a meeting at the office of Mr N. Georgiadies, Director of the Environment Service of the Ministry of Agriculture, Natural Resource and the Environment with the participation of Mr Malikides of SBP, Mr Jordanou of MJA and Mr Loizides of PROPLAN LTD. The TOR are given in Appendix III and interpreted in section 1.2 below.

The work was formally assigned to Proplan Ltd on the 27th of July 1998.

1.2 Terms of Reference

The TOR for this assignment are given in Appendix III. Herebelow they are interpreted as understood by the consultants (Proplan Ltd) and explained to MJA and SBP during the first inception meeting held on 02/09/98 in Pafos.

1. Odour Dispersion

   Describe the technology proposed. Run the computer simulation using meteorological data from Pafos Airport. If the model indicates possible nuisance creation to propose relevant mitigation measures and re-run the dispersion model.

2. Mitigation measures

   Will propose measures to prevent odours from spreading from the PS and the STP.

3. General issues

3.1 EIA on emergency facilities proposed.
Theses facilities are
(i) the standby generator(s) at the PS's and the STP
(ii) emergency overflows at the PS and the STP
(iii) emergency storage lagoon

3.2 EIA on the discharge of storm waters.
There are three storm water discharges. To investigate the effect on the natural drainage channels.

3.3 EIA on the sludge treatment and disposal.
This very large subject will address only the availability of solutions, their impact and their applicability to the Pafos STP.

3.4 EIA due to the transportation of septage.
Operating standards for vehicles and odour prevention measures.

3.5 Construction phase mitigation measures
Discussion of generally accepted practices

4. Review of reuse proposals and suggestion of further studies

   The treated wastwater reuse proposals are:
   (i) Irrigation locally
   (ii) Irrigation of hotel gardens and public spaces

(iii) Ground water recharge.

1. The purpose of the study is to prepare an Odour Dispersion Model for the proposed treatment plant and the 3 pumping stations at the already chosen sites. The consultants will take into accounts the technology proposed, following international accepted methods and standards, to prove whether nearby communities will be affected or not.

2. The consultants will propose relevant mitigation measures in case any nearby communities or other dwelling are effected.

3. In the course of the study the consultants will address in general the following:

   - The emergency facilities proposed by the design and assess the environmental impact.

   - The environmental impact due to the discharge of storm water both into the sea and natural watercourses.

   - The environmental impact due to sludge treatment and disposal.

   - The environmental impact due to transportation and treatment of septage.

   - Any mitigation measures in general to face environmental impact during construction stage.

4. The consultants will review briefly reuse proposals and suggest investigation and studies required.

1.3 Description of project

1.3.1 Sewerage system

For the sewerage system there can only by one main environmental criterion with long term effect. This is the maximization of the use of gravity over the entire service area, including lands, which can potentially become part of the built up area in the years to come.

Once this criterion is satisfied then within each catchment basin there must be the minimum number of SPS's to "correct" for the localized imperfections in the territory (i.e. a small ravine or hill etc) and a route to act as an emergency outfall.

In most circumstances, connecting industries to public sewer systems is sensible. It reduces the number of discharge points and thus the complexity and cost of monitoring and enforcement, provides the opportunity for better control of industrial effluent, and may be lower in total cost. Absolutely critical to success, however, is an industrial pretreatment program including regulations with specific limits on discharges of hazardous and toxic substances and other pollutants to public sewers, monitoring procedures, and enforcement capability. Otherwise, there is a risk of exposing water system personnel and components to hazardous materials, disrupting the treatment process, transporting toxic pollutants to receiving waters or the land, and contaminating treatment plant sludge so severely it cannot be put to beneficial use or even disposed of without difficulty.

The Water Pollution Control Law prescribes the conditions under which industrial liquid effluents can be discharged giving the limits to be met. Wastewater analysis results from Nicosia show what is indeed a paradox in that limits for BOD and COD are 300 and 600 mg/l respectively while the raw sewage values going to Mia Milia and Anthoupolis STP's are consistently higher (double) the above limits.

The possibility of industrial liquid effluent from multiple small sources inside city boundaries must not be excluded. Currently the limit of effluent discharge without a permit is $2m^3$ per day. There is little enforcement over this provision and many small operations in town using chemicals and solvents could discharge in the sewers.

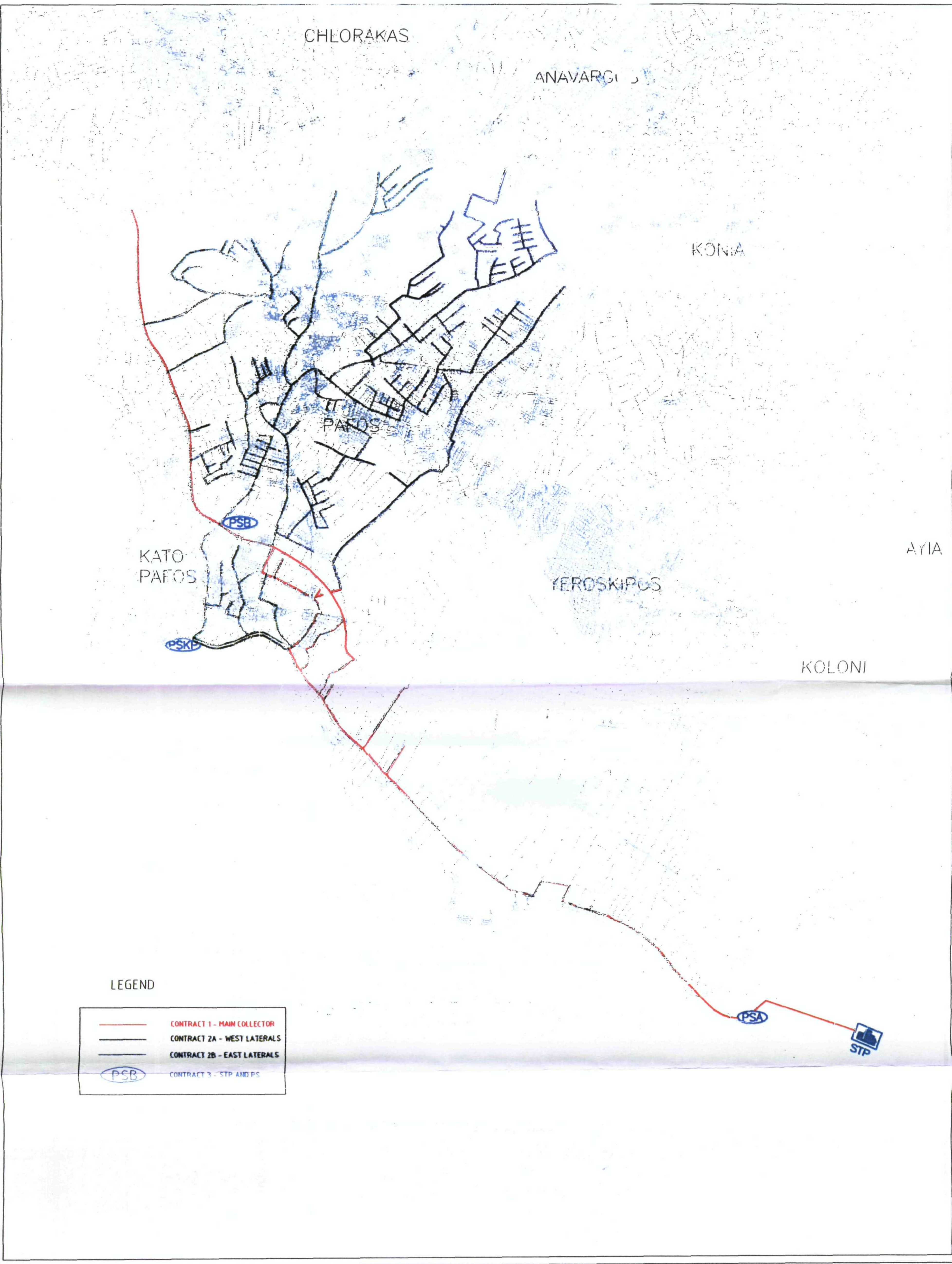
The creation of Light Industry (Craft Zones-Viotechnikes Perioches) is a potential hazard for the sewerage collection and treatment system as most of the establishments will be under the $2m^3$ per day limit.

1.3.2 Drainage system

The drainage system is designed to collect rainwaters from the built up areas and direct them towards natural, existing drainage passages, which discharge to the sea and which have been used for years. One such passage (Katiskandaris) is almost completely covered. Two 1500 mm diameter pipes will be installed to complete the coverage. The other passages will need some improvement in order to:

- Define the stream to improve bed, possibly by concreting the bottom and banks

- Cover parts of the stream to improve aesthetics, minimize the risk of fires, minimize unauthorized dumping, prevent the harboring of snakes and rodents in built up areas, etc.



CONTRACT PACKAGING FOR THE SEWERAGE AND DRAINAGE WORKS

FEASIBILITY STUDY FOR STORMWATER DRAINAGE AND SANITARY SCHEME FOR PAFOS AREA AND ENVIRONS

LOUIS BERGER INTERNATIONAL, INC.
in association with
MG JORDANOU AND ASSOCIATES

➢ Clear some of the vegetation if is created the impression of an uncontrolled, wild area. Vegetation is not only a nesting place for wild life can also act as a filter to prevent the discharge of debris to the sea. The latter of course created the obligation for seasonal cleaning and clearing.

This is compatible with the original design.

1.3.3 STP site

The site selected for the STP is shown on Map. I in Appendix IV. The site layout is shown in Map II in the same Appendix. The photographs on the following pages show the site as it is today. Better photographs could not be taken due to the flatness of the topography and the trees. Aerial photography in the area is restricted. The site is in the Paliochorapha area of Achelia and it is about 2000 metres from the nearest house and 1800 metres from the nearest residential plot.

The terrain is flat with a sea elevation of 3 – 4 metres with a very slight slope from inland toward the sea. The general area is wholly devoted to agriculture and it is irrigated. According to the project scheme the whole STP compound will be surrounded by even more trees thus making it invisible from the ground.

1.3.4 STP Location and process

Treatment facilities require land; siting them can lead to protects and objections because treatment and disposal works can sometimes cause nuisances in the immediate vicinity, at least occasionally, leading to loss in the values of land and the direction of development toward other areas. Care will be taken to site treatment and disposal facilities where odours or noise will not disturb residents or other users of the area and to include in the project mitigation plan provisions to mitigate or offset adverse impacts on the human environment.

Without any final design details on the particular treatment technology to be employed one must of necessity generalize. However since the treatment is outlined in the Draft Final, Design Report (June 1998), the following four steps of operations are considered:

- Pretreatment
- Primary treatment
- Secondary treatment
- Tertiary treatment

Based on this classification a matrix is formed with regard to the:

- Liquid stream
- Solid stream
- Gas stream

This matrix is presented in the table 1.1 below where typical operations are mentioned. Assuming that the treatment is such as to ensure the production of liquid effluent to the desired standards then other than leaking ponds and the production of liquid sprays there are no other negative environmental effects from the liquid stream.

This can not be so generally stated for the solid and gas streams.

The solid stream will consist of:
- Screenings
- Grit
- Grease and scum
- Sludge

Pretreatment
2 bar racks
2 Grit removal chamber

Primary treatment
2 settling basins

Secondary treatment
4 basins (completely mixed biological reactor) (aeration system unspecified)
2 clarifier

Sludge digestions
2 digesters (anaerobic option)
2 digesters (aerobic option)

The process proposed is that of activated sludge leading to TE of tertiary treatment level as per the existing standards. The maximum concentrations are given in the Draft Final Design Report (June 1998) as follows:

TSS	10
BOD_5	10
NH_4^+ - N	2
N – total	10

Final effluent to be chlorinated.

The treatment plant consists of the following (extracted from DFDR – June 1998 Table by Proplan Ltd).

Table 1.1
Emission generation matrix

	Liquid stream	Solid stream	Gas stream
Pre treatment	➢ Automatic Bar Screan ➢ Grit and scum removal ➢ Flow metering ➢ *Septage reception / storage / proportioning*	➢ Washing ➢ Dewatering ➢ Conditioning ➢ Grits washing ➢ *Grease and scum management* ➢ Truck removal to landfill	➢ Enclosed operation ➢ *Air scrubbing or other treatment*
Primary Treatment	➢ Settling	➢ Aerobic stabilization tanks	➢ Enclosed ➢ Air scrubbing or other treatment
Secondary Treatment	➢ Aeration / Oxidation ➢ Denitrification ➢ Settling	➢ Sludge dewatering ➢ *Sludge conditioning* ➢ *Sludge disposal*	➢ *If fine bubble aeration (basins can be enclosed)* ➢ If rotors or surface aerators basins cannot be enclosed
Tertiary Treatment	➢ Coagulation ➢ Rapid sand filters ➢ Chlorination	➢ backwash solids: recirculation to head tank	➢ No gas stream other than escape of chlorine in case of major fault, accedent or act of sabotage

The gas stream will contain all escaping odours as shown in section 2.1 the Primary Treatment Stage has already been decided to be enclosed in order to contain odours generated at the exit of sewage from the mains.

The location and the layout of the Pafos STP is shown in the maps in Appendix VIII.

The Paleochorafa area where the STP will be constructed about 2 km lies to the Southwest of Achelia village.

In relation to the prevailing winds this is in a favourable position minimizing the probability of odour movement towards the village.

2.0 ODOUR DISPERSION MODEL

2.1 Introduction

As wastewater becomes septic, gases including methane, nitrogen, carbon dioxide and hydrogen sulphide are released. Methane and hydrogen sulphide are flammable, hydrogen sulphide is toxic, and the other gases are asphyxiants. The hydrogen sulphide is corrosive itself and reacts bacterially to form sulphuric acid.

Low hydrogen sulphide concentrations are readily identified by a repulsive rotten egg smell and are detectable in concentrations of 0.0001%.

2.1.1 Sources of odour in Sewage Treatment and Disposal

A precise identification and quantification of sources of odour from a sewage treatment plant is difficult due to size and number of sources. This analysis reviews potential sources of odour.

Odours from sewage treatment works are usually the result of anaerobic biological activity. Production of odours from domestic sewage can be compounded by the addition of some types of industrial waste.

Principal wastewater treatment plant odour sources arise from the following areas (highlighted are the most common offenders):

- septic wastewater containing hydrogen sulphide and other odourous compounds
- **screenings and unwashed grit**
- **septage handling facilities**
- scum on primary settling tanks
- organically overloaded biological treatment processes
- sludge thickening tanks
- sludge conditioning and **dewatering facilities**
- sludge digesting and composting operations
- transportation and re-use of sludge.

With proper attention to design and good housekeeping, treatment plant odours can be minimised. Covering and odour control techniques and equipment will need to be applied at various stages of the process used in the wastewater treatment plant (see section 3.0).

The odour of fresh wastewater is faint and not necessarily objectionable. As the dissolved oxygen in wastewater diminishes, however, anaerobic conditions are created. When the wastewater is putrefied by anaerobic bacteria, foul-smelling gases start to form. If the stale condition exists for an extended period, the wastewater will become septic, bubbles of gas may rise to the surface, and black scum may be present. Such conditions are created by long pipeline runs in forcemains.

The wastewater entering the wet well of a pumping station sometimes may be stale or septic because of the travel time through long and flat sewers, or because of its high sulphate content. Fortunately, several techniques may minimize the generation of these offensive odours (see section 3.0).

In wastewater, any organic matter containing sulphate and nitrogen that is being decomposed by anaerobic bacteria may give off obnoxious odours. The substances emitted may be classified as inorganic gases and organic vapours. The inorganic gases include hydrogen sulphide (H_2S), ammonia, (NH_3), carbon dioxide (CO_2), methane (CH_4), nitrogen (N_2), oxygen (O_2), and hydrogen (H_2). Except for hydrogen sulphide and ammonia, most of the inorganic gases are odourless.

Some of the odour-producing substances of organic origin are mercaptans, methylsulphides, amines, indoles, skatoles, and phenolics. Some organic acids, aldehydes, and ketones also may offend certain individuals.

Table 2.1 lists the most frequent compounds causing complaints

TABLE No. 2.1 ODOURS:
TOP 10 PUBLIC OFFENDERS

Inorganics	Organics
Hydrogen Sulphide Ammonia	Amines Skatoles Indoles Mercaptans Disulphides Butyric, Stearic, and Oleic acids

The sewer odour normally is caused by a mixture of the inorganic gases and the organic vapour.

The objectionable smell that may be present at a pumping station usually is caused either by the odour released from the stale wastewater as it enters the station or by odour produced in the wet well of the station, when the wastewater becomes stale or septic. Odours-generally can be controlled by additions of oxidation chemicals, pH adjustment, metalic salts, masking odours with chemical additives, aeration, or adsorption by activated carbon (More details on odour control measures are given in section 3.0).

2.1.2 Quantification of odour

Quantification of Odour

There is no simple relationship between odour characteristics of individual compounds. Most compounds are odourous when present at low concentrations. Although analytical techniques such as gas chromatography, coupled with mass spectrometry or other compound specific detectors can be used, the human nose remains the only reliable guide to the presence and strength of an odour.

The accepted method to quantify the strength of an odourous gas is to determine the number of dilutions required to render it odour-free. The establishment of odour thresholds in this way has been undertaken using a variety of techniques for many years. Research has led to a range of odour thresholds for a given chemical because of differences in chemical source and purity.

Odour thresholds are commonly referred to as:
absolute - dilution at which none of the panellists can detect odour;
50% detection - dilution at which half the panellists can detect the odour;
50% recognition - dilution at which half the panellists can recognise the odour;
100% recognition - dilution at which all panellists can recognise the odour.

The 50% recognition threshold is most commoniy referred to as the odour threshold.

To estimate production of H_2S, in force mains one can use the following formula from Boon:

$$C=K_4*L_{COD}*t_s*(1+K_5*d_1)/d_1*1.07^{(T-20)}$$

Where:
C = Concentration of sulphide produced, mg/l
L_{COD} = Concentration of COD in sewage, mg/l
D_l = Diameter for sewer force main, cm
t_s = Retention time in sewer, min
T = Temperature of sewage, °C
K_4 = Constant - 0.00152
K_5 = Constant - 0.004

Assuming a temperature of 30°C in summer months and an average COD concentration of 600 mg/l, the H_2S production can be calculated as shown in Table 2.2, for various retention times and force main diameters.

Table 2.2
Calculated H_2S concentration in force mains, mg/l

H₂S concentration, mg/l					
K4=0.0002 K5=0.004 L_{COD}=600 T=30°C	$C=K_4*L_{COD}*t_s*(1+K_5*d_1)/d_1*1.07^{(T-20)}$				
	d_1				
Ts min	200 mm	400 mm	500 mm	600 mm	700 mm
0	0.00	0.00	0.00	0.00	0.00
20	1.94	1.04	0.86	0.74	0.66
40	3.88	2.08	1.72	1.48	1.31
60	5.81	3.12	2.58	2.22	1.97
80	7.75	4.16	3.44	2.97	2.62
100	9.69	5.20	4.31	3.71	3.28
120	11.63	6.24	5.17	4.45	3.94
140	13.56	7.28	6.03	5.19	4.59
160	15.50	8.32	6.89	5.93	5.25
180	17.44	9.36	7.75	6.67	5.90
200	19.38	10.41	8.61	7.42	6.56
220	21.31	11.45	9.47	8.16	7.22
240	23.25	12.49	10.33	8.90	7.87
260	25.19	13.53	11.19	9.64	8.53
280	27.13	14.57	12.06	10.38	9.19
300	29.06	15.61	12.92	11.12	9.84
320	31.00	16.65	13.78	11.86	10.50
340	32.94	17.69	14.64	12.61	11.15
360	34.88	18.73	15.50	13.35	11.81
380	36.81	19.77	16.36	14.09	12.47
400	38.75	20.81	17.22	14.83	13.12
420	40.69	21.85	18.08	15.57	13.78
440	42.63	22.89	18.95	16.31	14.43
460	44.56	23.93	19.81	17.06	15.09
480	46.50	24.97	20.67	17.80	15.75
500	48.40	26.01	21.53	18.54	16.40
520	50.38	27.05	22.39	19.28	17.06
540	52.31	28.09	23.25	20.02	17.71
560	54.25	29.14	24.11	20.76	18.37
580	56.19	30.18	24.97	21.50	19.03
600	58.13	31.22	25.83	22.25	19.68

Justification for the use of these parameters in the calculations, which in any case are indicative estimations, can be found in the measurements of raw sewage inlet temperature at Mia Milia In Nicosia and the chemical analysis for disolved and air space sulphides in the force mains of the existing system in Nicosia. In the dispersion model (see section 2.2) worst case scenario conditions were used as is quite normal practice.

Measurements of sulphides by the Sewage Board of Nicosia laboratory show values about 10 to 15 mg/l in the mains. Gas-liquid equilibrium will result in much higher values in air (on a weight basis). These can range into the thousand ppm levels as is of course confirmed by the analyses presented in Table 2.3a, 2.3b and 2.3c.

As is the international practice the level of removal of H_2S is often set by the local environmental authority (in Cyprus it will be the Ministry of Labour, Factory Inspectorate) on a mass of H_2S per unit of production capacity of the plant or per unit time. In other cases dispersion models are performed to ensure that a maximum limit of H_2S at ground level is not exceeded. Required removal efficiencies encountered to date have ranges from 85% to over 99.9%, which are achievable.

In case studies available with the consultants, permitted emission limits circa 70 ppmv of H_2S have been given in the USA. However odour treatment units can achieve consistently levels of 10 ppmv without difficulty.

A standard proposed in Holland is $<5ouE/m^3$ for more than 98% of hours. This seems to correlate well with complaint. At first consideration this appears to follow a rule of thumb that no odour will be a nuisance until it is at lease five to ten times its threshold concentration.

The ouE/m^3 is the "European" odour unit, which is numerically equal to the number of dilutions by odour free air of an air sample until 50% of a selected human panel fail to detect odour. For enclosed sources the odour strength in ouE/m^3 multiplied by the flow rate of emitted air is the odour emission rate in ouE/s, which can be used in dispersion modeling.

Given the difficulties in quantification of odour sources from sewage treatment plant, some progress can be made for assessment purposes by the use of atmospheric dispersion modelling.

Odour nuisance generated by sewage treatment processes is often linked to releases of hydrogen sulphide (H_2S). An assumed odour threshold of H_2S is 0.0005 ppm, or $0,75mg/m^3$ is used. This value has been selected for the modelling assessment because it is more conservative than other thresholds quoted for H_2S, and is in line with the general theme of the assessment which is to take a conservative view of the potential impact.

Odours released during day time are acted upon by the UV portion of the spectrum and are destroyed faster than those released at night, as they are dispersed. Dispersion depends on atmospheric conditions such as wind speed and direction, stability, thermocline inversions etc. In order to err on the safe side dispersion modelers avoid to take into account the destruction of chemical species by atmospheric reactions choosing to work on the basis of statistically determined odour thresh old limits.

2.2 Air Dispersion model

2.2.1 Air Pollutant Dispersion Model - *PLUME PLUS*

The **PlumePlus** software package was developed by, TNO, Division of Technology for Society, Department of Environmental Chemistry in the Netherlands. Version 1.1 was published in March 1990.

Table 2.3a
Total Sulphides Content in Existing Sewers in Nicosia - 1998

Main Trunk Sewer	Total Sulphides (mg/l)					
Date of Sample	T1	TA	TB	TC	TD	TE
28-07-98	6.5	10.3	5.3	4.9	6.3	16
05-08-98	6.4	14.5	3.1	3.8	8.1	2.7
26-08-98	8.4	13.9	4.9	5.1	7.4	15.6
01-09-98	9.8	14.2	4.2	6.8	7.4	9.3
23-09-98	11	9.6	4.4	6.6	8.8	14.5

Table 2.3b
Soluble Suldphides Content in existing Sewers in Nicosia - 1998

Main Trunk Sewer	Total Sulphides (mg/l)					
Date of Sample	T1	TA	TB	TC	TD	TE
28-07-98	5.3	-	1.6	-	-	1.4
05-08-98	4.9	12	2.6	-	-	1.5
26-08-98	6.9	9.7	1.5	-	4.0	12.7
01-09-98	5.2	10.9	2.4	-	4.6	7.0
23-09-98	5.9	5.6	2.1	-	4.8	11.0

Table 2.3c:
Hydrogen Sulphide Content in the Headspace of Existing Sewers in Nicosia - 1998

Main Trunk Sewer	Total Sulphides (mg/l)					
Date of Sample	T1	TA	TB	TC	TD	TE
28-07-98	9.5	0.5	0	1.5	15.0	5.5
05-08-98	-	-	-	-	-	-
26-08-98	4.5	0	0	7.5	16	12
01-09-98	6.5	0.5	0	2	10.5	1.5
23-09-98	4.5	0	0	2.5	0.5	15

The so called National (Netherlands) Model was the result of a joint approach involving research institutes, government and industry, in order to come to an agreement on the computational method to be employed for calculating the dispersion of air pollution. The software was commissioned by - and developed in close cooperation with the Dutch Ministry of Environment (VROM) and the Dutch National Institute of Public Health and Environmental Protection (RIVM) for use by provincial authorities It is a Gaussian plume model.

The Gaussian plume model is similar to many others of its kind. It assumes that the concentration distribution in a plume of pollution has a Gaussian shape, both in the horizontal and in the vertical direction.. The plume behaviour depends on the height and the heat output of the source and on the meteorological parameters wind speed, wind direction and stability, which are assumed constant during the plume travel. The heat output determines how high the plume rises above the source due to its buoyancy. When the plume has enough buoyancy to reach the top of the mixing layer, it may penetrate the overlying inversion layer partly or entirely. The mixing layer height is a function of the stability of the atmosphere. The width and height of the plume are defined by the horizontal and vertical dispersion parameters σy and σz respectively according to the Pasquill classification. These two parameters depend on the distance from the source, the aerodynamic roughness of the surface and the surface height.

Like all models the model used in the present case makes several assumptions and has several restrictions as described briefly below:

- Suitable for source – receptor distances of 0 to 25 km (max).
- Applicable only for gaseous < (10μm) diameter and inert species.
- Not suitable for cases where short range dispersion is influenced by obstacles such as buildings in the immediate vicinity.
- Assumes complete reflection by the ground.
- No chemical reactions or other physical processes are considered.
- Mean wind velocity (u) is representative for the total diffusion layer.
- No wind shear is encountered. Wind direction is considered to be the same in all layers.
- Wind velocity should be >0,5 m/s
- Stationary and homogenous turbulence (Taylor Theory)
- Narrow plume approximation.

In addition to several dispersion models, the **Plumeplus** software package also comprises a large number of data bases as well as a shell facility. Data on sources, receptor grids, meteorology and background concentrations are stored as files. The shell coordinates communications between user, files, computational models and the PC operating system. The shell consists of menus and forms providing access to files (for data utilization, updating, modification or deletion) and allowing models to be run and controlled.

For the user, the general procedure is to first input source data into a source file and then perform the required computations using site-specific files with meteorology, and background concentration data.

Detailed description of the model, its operation, inputs and database management is not considered within the scope of the present paragraph. However, both the Model General Manual and the computation proceedures WILL BE AVAILABLE FOR ANY POSSIBLE FURTHER EXPLANATIONS at Proplan Ltd.

The **Plumeplus** model is also installed and is being used by the Ministry of Labour and Social Insurance, Factory Inspectorate in Nicosia.

2.2.2 Underlying Theory of air dispersion modeling

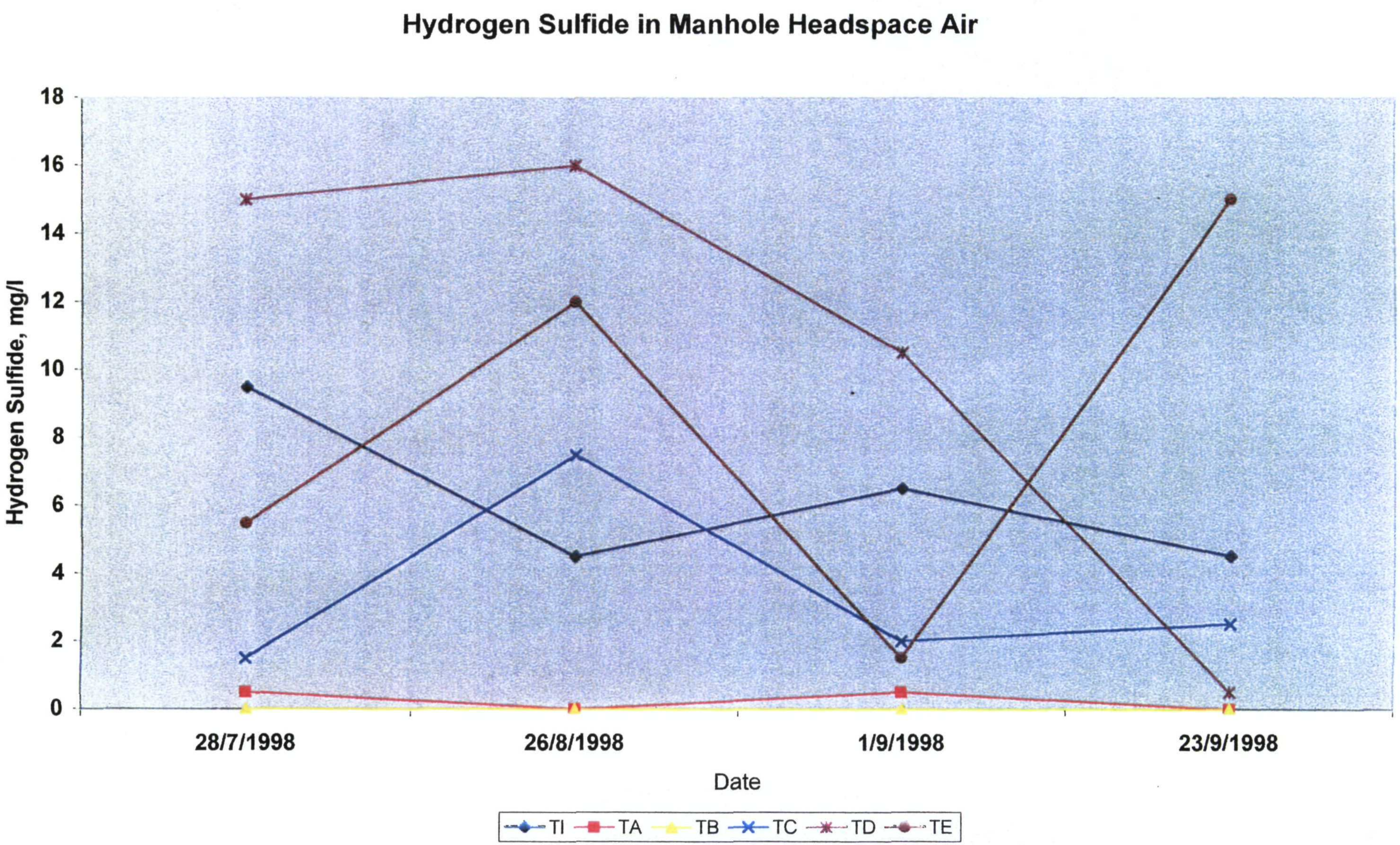
The underlying theory of most air dispersion models, is a single equation, which engineers can use as a design and operating tool to estimate the impact of process emissions. While this method may underpredict or overpredict a point concentration, it does give a feel for the magnitude of the emission's effects on the community. It can be used effectively as a process-screening tool to determine if more-complex modeling is warranted.

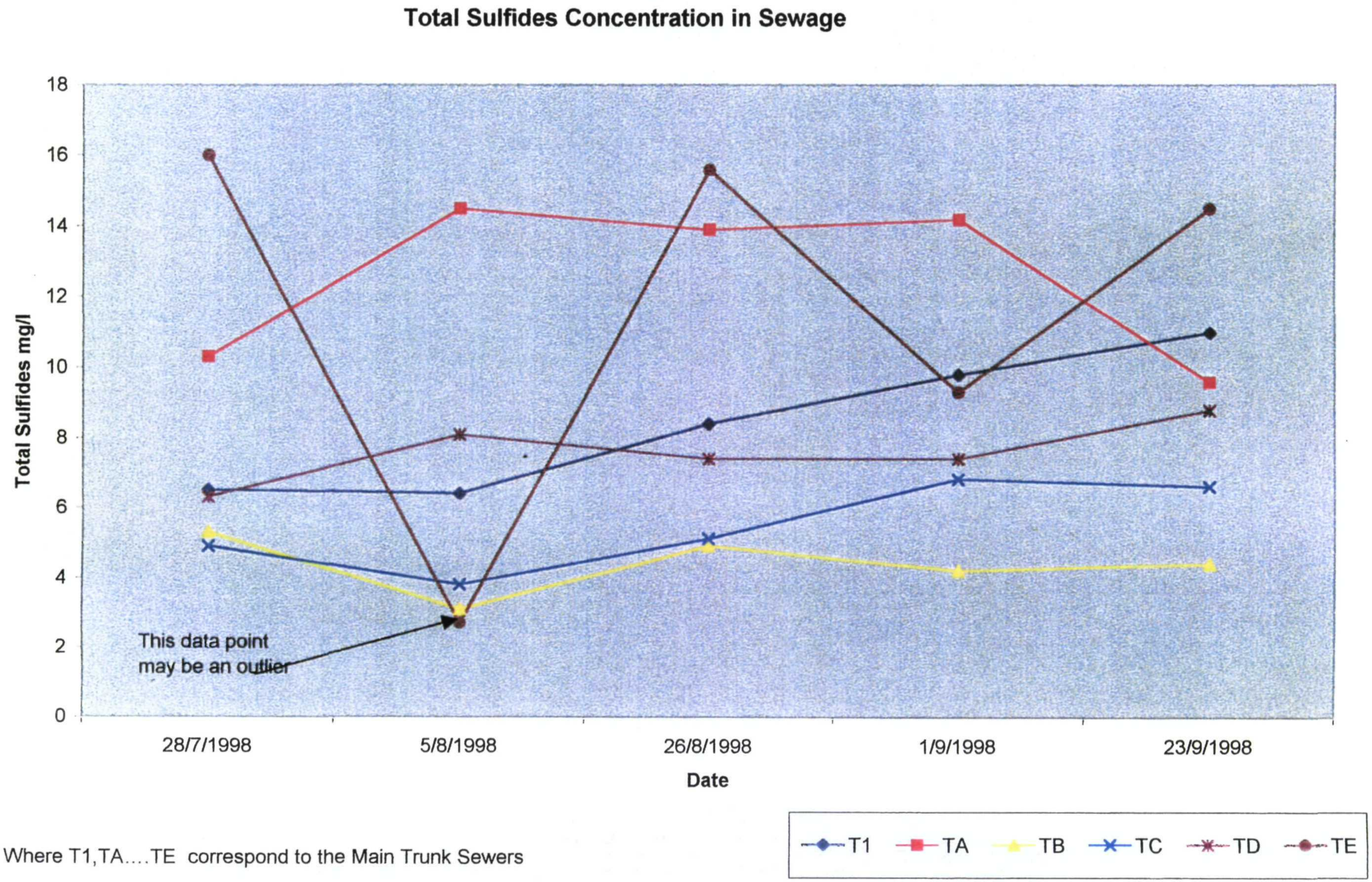
To use this method, one will have to make some specific assumptions based on the location and meteorological complicating factors, such as hilly or mountainous terrain, building interference, intermittent operation, and long-term operation, that effect the accuracy of the modeling.

There are many types of air emission models. Most are based on Eq. 1, a double Gaussian distribution used for long-term emission modeling of continuous processes.

Figure 2.1 shows a graphical representation of the modeled emission. The emission leaves the stack and travels straight up above the stack a distance, which is referred to as "plume rise". Then the emission is blown straight downwind along the x direction, where the plume disperses in the y and z planes until the effect becomes trivial. For the present case purposes, it is assumed that the plume rise is negligible.

The wind direction and speed are critical inputs to an air emission model. A snapshot of a year's data is often shown as a windrose, which is a frequency distribution by wind direction and speed ranges. Windroses are normally constructed using weather data for the nearest city. This information is used to select one or two typical windspeeds for estimating emissions: the median wind-speed may be the most appropriate. Figure 2.2 shows the windrose from Pafos Airport.


Hydrogen Sulfide in Manhole Headspace Air
18
16
14
12
10
8
6
4
2
0
Hydrogen Sulfide, mg/l
28/7/1998
26/8/1998
1/9/1998
23/9/1998
Date
TI
TA
TB
TC
TD
TE



Where T1,TA....TE correspond to the Main Trunk Sewers

Another critical input to modeling is the local meteorological conditions. These are categorized by meteorologists into six stability classes, A though F:

A = very unstable
B = moderately unstable
C = slightly unstable
D = neutral
E = slightly stable
F = stable

Tables 1-3 and the accompanying figures show the conditions corresponding to these stability classes

The stability class is important because it determines the standard deviations (σ_y and σ_z) required to calculate the Gaussian distribution. Values of σ_y and σ_z are available in graphical form or can be calculated using the following equations and the curve-fit parameters in Table 2.

$\sigma_y = \alpha x^b$
$\sigma_z = cx^d + f$

Downwind air concentrations are linear with respect to emissions. This relationship can be used to evaluate alternatives in engineering systems.

Note that σ_y and σ_z values vary with atmospheric stability and downwind distances. Atmospheric stability represents the mixing nature of the atmosphere. For example, nighttime atmospheric conditions are generally represented by an atmosphere that is either stable (characterized by reduced vertical mixing) or neutral (characterized by insignificant vertical mixing).

By comparison, daytime atmospheric conditions are typically represented by either a neutral (i.e., one characterized by vigorous vertical mixing) atmosphere. For nighttime releases, we have assumed a stable atmosphere. For daytime release, a neutral atmosphere has been assumed.

The Odour Impact (OI) Model concept was developed to facilitate the analyses of odour problems in the community and industry. The model is a graphical representation of the response of a sample of the human population (odour panel) to the stimulus of a specific odour. The model, shown in Figure 2.3, is for the odour of hydrogen sulphide (H_2S).

In developing the model, increasing concentrations of the odourant are administered to the panel members who record their reactions in terms of detection, complaint, and annoyance. These reactions are graphed as functions of concetration (it is also possible to express the curve mathematically as a hyperbolic tangent), and it is possible by looking at the graph to pick out a concentration acceptable for standard setting or other applications. For example, if we wanted to set a standard for hydrogen sulphide (H_2S), we could set it at 5.5 micrograms per cubic meter (μg/m³) which is the 50 percent detection level.

An interesting application of the model is its use in making a decision about the percentage of the population that will be allowed to detect the odour.

The odour dispersion model has been run with several H_2S generation rates and at various atmospheric conditions.

The results are presented in a summary graph showing H_2S concentrations at various distances from the source. The Threshold Limit Value is also shown for comparison.

It can be seen that provided measures are taken at the source, to prevent the escape of odorous gases then there will be no effect beyond the plant boundaries.

Provided odourous gases are contained, collected and vented to atmosphere through the appropriate treatment system then there will be no odour nuisance problems.

This argument assumes that the panel is a true sample of the community. A possible approach for selecting the present response is to use 16 percent, because the majority of the people will be between plus and minus one standard deviation (sigma), i.e., 68 percent. If this middle group is protected, then the average person is protected, and only the 16 percent of people with above average smelling ability will be allowed to suffer the odour insult.

2.3 Modelling results

Using data from the Draft Final Design Report, the Boon Formula and typical COD data from past analyses from Mia Milia and Anthoupolis in Nicosia the H_2S concentration at the STP head-works is likely to reach values of even 5kg/hr. To demonstrate how high this value is, in relation to odour nuisance, the dispersion model was run with only 1kg/hr using the available weather data. The model predicted that the smell will be felt down-wind upto 1.5 kilometres. Naturally this is not acceptable. It is rather obvious that odour control measures must be installed at the headworks to provide effective degassing and odour removal. Such technology exists and it can produce consistently 99.9% removal. It is noted here again that the proposed design provides for such measures anyway.

To demonstrate the effect of treatment, the dispersion model has been re-run with a 1kg/hr generation rate and at 90% and 99% removal efficiency. The predicted results show that the H_2S threshold limit value would be expected at about 0.25km and 0.075km (occasionally) respectively.

The STP design which already provides for H_2S removal will also have the provision for possible future enclosure of all processes that can be offensive with respect to smell. Such areas will be sludge handling points, screening and grit removal points, digesters etc.

Figure 2.4 shows one of the model's graphical outputs using a total H_2S release rate of 10gr/hr. The threshold limit value of 0.5ppb i.e. the value at which 50% of persons will detect the smell is indicated with a pink colour.

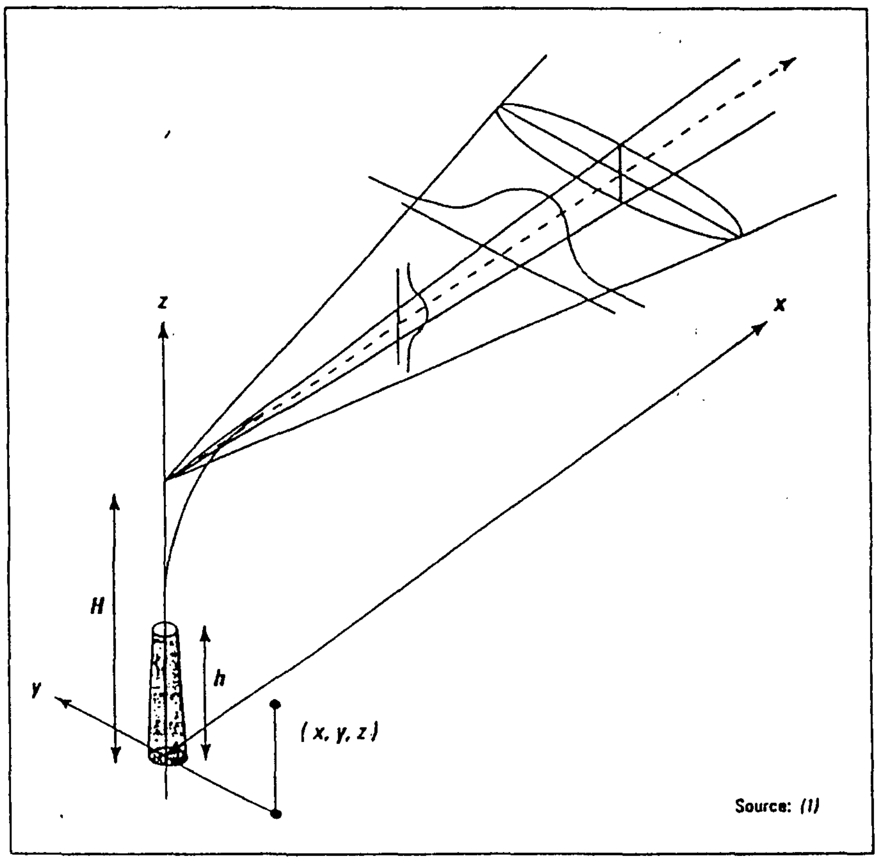
2.3.2 Pumping stations

1. The dispersion model used is not applicable for urban areas. It has however been used for PSA with an emission rate of 0.01 kg H_2S/hr which assumes that an odour control device will be in place and in good working order and consequently any modeling will not be of any value. Even for PSA where the model was run the isopleth lines showed very low values only up to a few meters from the outlet. The particular pumping station is on the coast where there is even a slight breeze most of the time. This aids dispersion further. With odour control devices in place none of the pumping stations will be a source of odour

$$C = \frac{Q}{2\pi u \sigma_y \sigma_z} \exp\left(-\frac{1}{2}\frac{y^2}{\sigma_y^2}\right)\left\{\exp\left(-\frac{1}{2}\frac{(z-H)^2}{\sigma_z^2}\right) + \left(-\frac{1}{2}\frac{(z+H)^2}{\sigma_z^2}\right)\right\}$$

C = point concentration, μg/m³
H = virtual stack height (stack height + plume rise), m
Q = mass flow of contaminant, μg/s
u = windspeed, m/s
x, y, z = ground level coordinates of stack, m
σ_y = standard deviation in y plane, m
σ_z = standard deviation in z plane, m

Equation 1.



■ *Figure 1. Gaussian air model coordinate system.*

Table 1. Stability classifications for meteorological conditions.

Surface Wind Speed, m/s	Day — Solar Insolation: Strong	Moderate	Slight	Night — Cloudiness*: Cloudy	Clear
<2	A	A–B	B	E	E
2–3	A–B	B	C	E	E
3–5	B	B–C	C	D	E
5–6	C	C–D	D	D	D
>6	C	D	D	D	D

*Meteorologists divide the sky into eight sections to judge cloud cover. If four or more sections have clouds, the sky is considered cloudy; if three or fewer sections have clouds, the sky is considered clear.

Source: *(2)*

Table 2. Parameters for calculating σ_y and σ_z for each stability class.

Stability Class	$x<1$ km: *a*	*b*	*c*	*d*	*f*	$x>1$ km: *c*	*d*	*f*
A	213	0.894	440.8	1.941	9.27	459.7	2.094	–9.6
B	156	0.894	106.6	1.149	3.3	108.2	1.098	2
C	104	0.894	61	0.911	0	61	0.911	0
D	68	0.894	33.2	0.725	–1.7	44.5	0.516	–13
E	50.5	0.894	22.8	0.678	–1.3	55.4	0.305	–34
F	34	0.894	14.35	0.74	–0.35	62.6	0.18	–48.6

Source: *(3)*

FORMULAS RECOMMENDED BY BRIGGS FOR
$\sigma_y(x)$ AND $\sigma_z(x)$; $10^2 < x < 10^4$ m,
OPEN-COUNTRY CONDITIONS

Stability Class	σ_y, m	σ_z, m
A	$0.22x(1 + 0.0001x)^{-1/2}$	$0.20x$
B	$0.16x(1 + 0.0001x)^{-1/2}$	$0.12x$
C	$0.11x(1 + 0.0001x)^{-1/2}$	$0.08x(1 + 0.0002x)^{-1/2}$
D	$0.08x(1 + 0.0001x)^{-1/2}$	$0.06x(1 + 0.0015x)^{-1/2}$
E	$0.06x(1 + 0.0001x)^{-1/2}$	$0.03x(1 + 0.0003x)^{-1}$
F	$0.04x(1 + 0.0001x)^{-1/2}$	$0.016x(1 + 0.0003x)^{-1}$

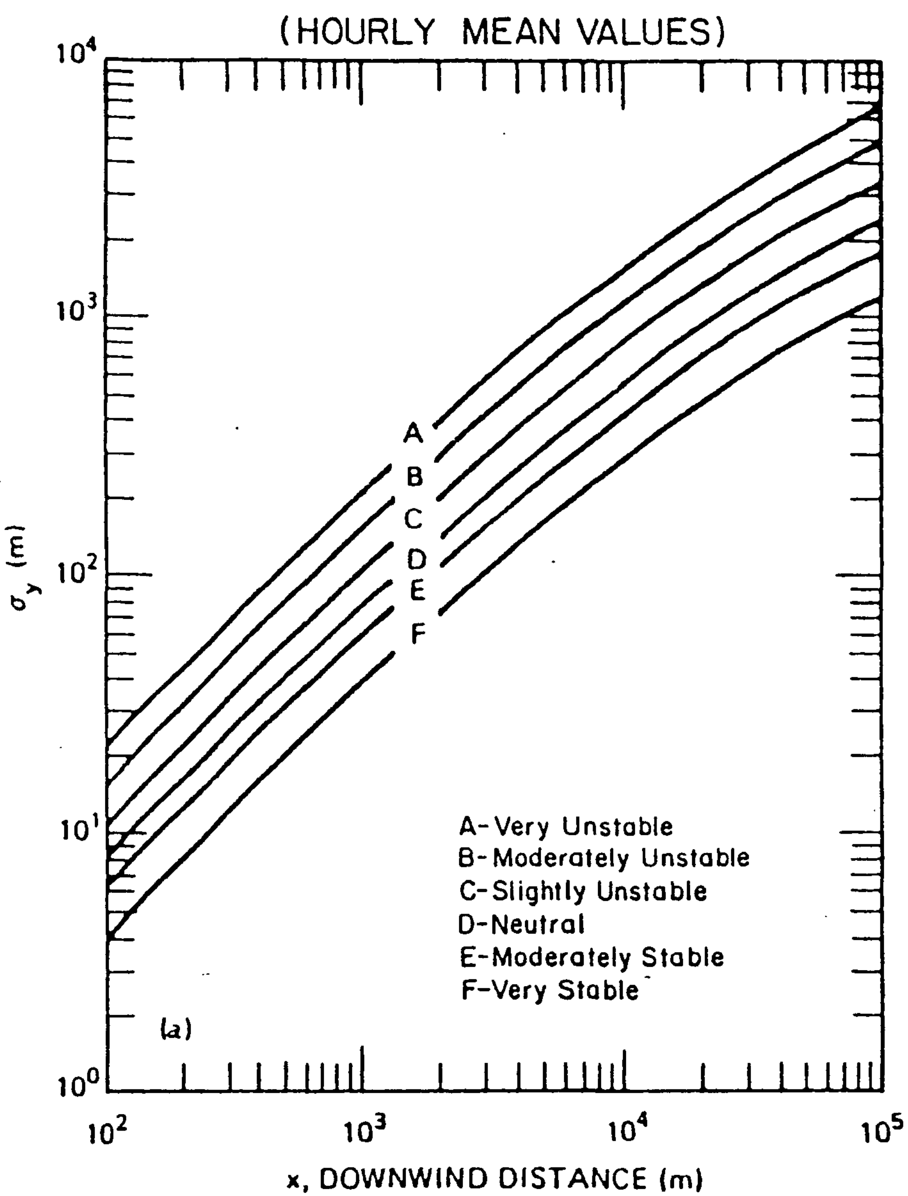


FIG. IV-6 HORIZONTAL STANDARD DEVIATIONS OF A PLUME. In the dispersion equations, the crosswind plume standard deviations are functions of distance (x) and meteorological conditions. Six such plots are given in this figure. The curves are tentative beyond 10,000 m, since only limited experimental data have been collected beyond that distance.

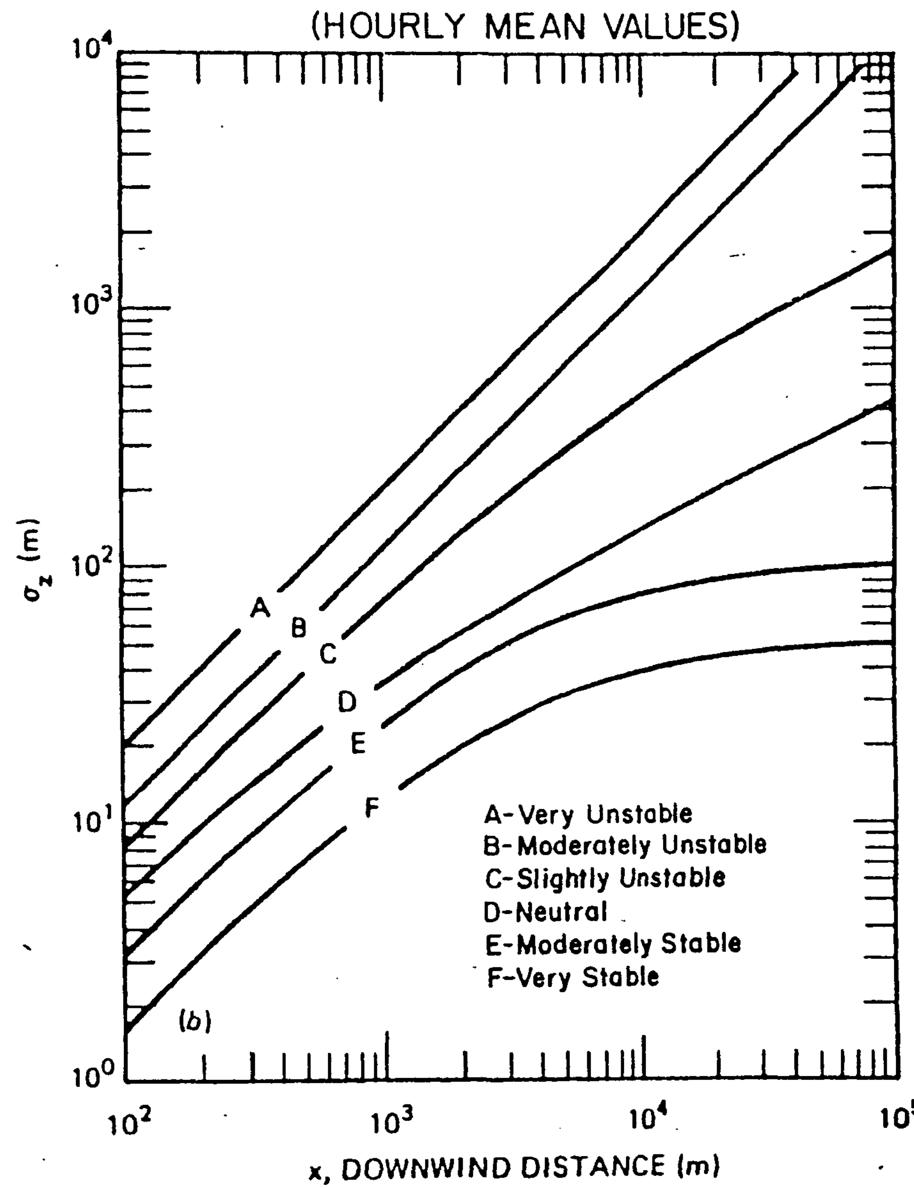
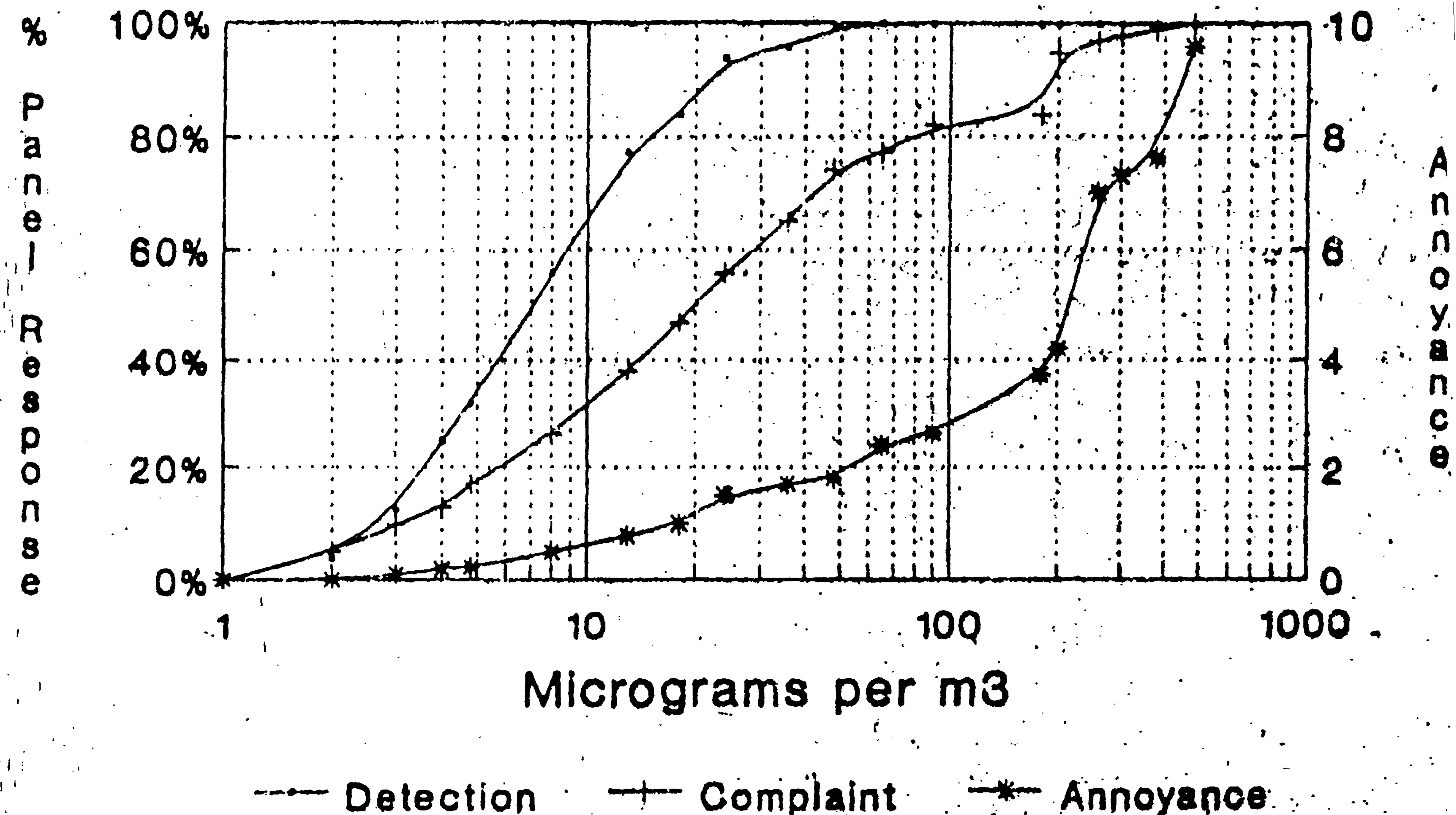
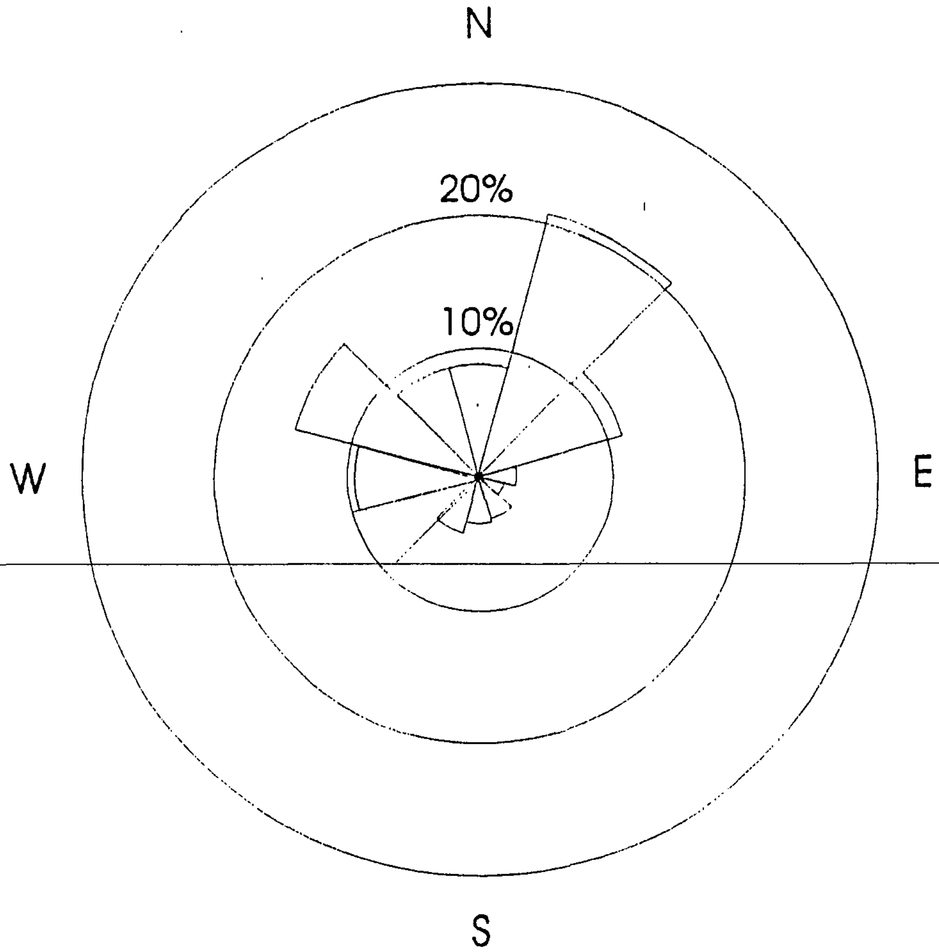
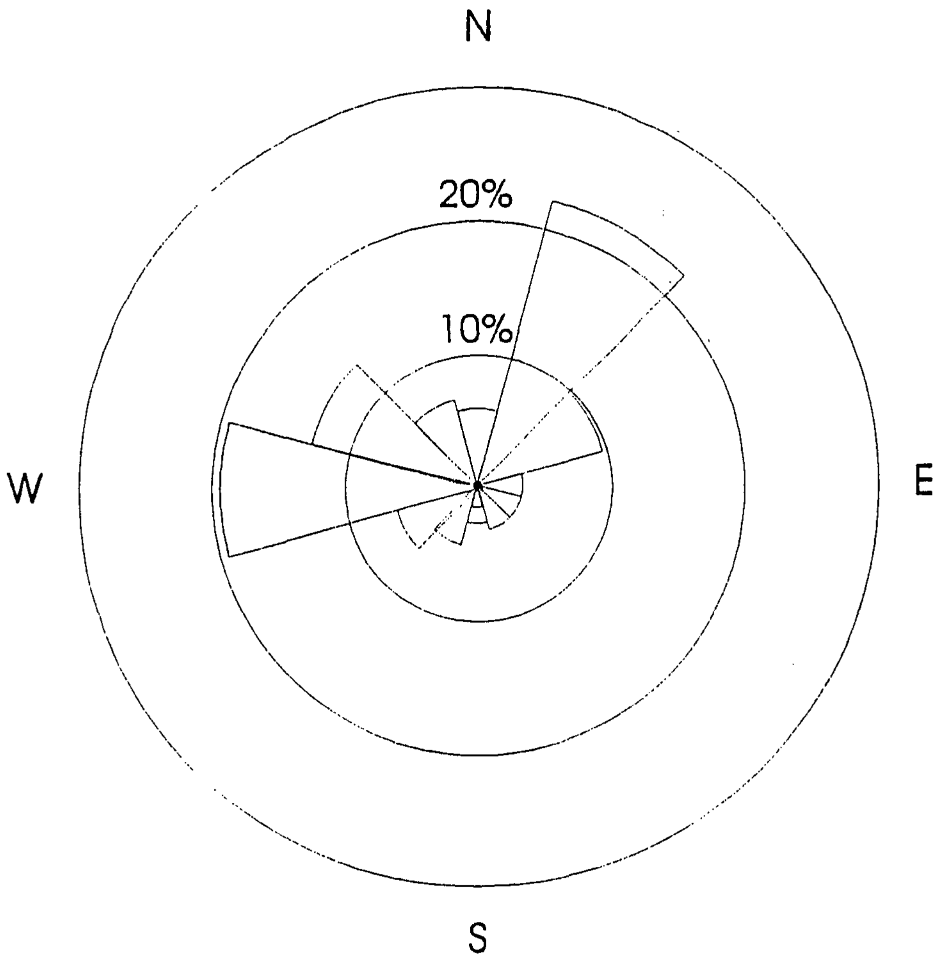


FIG. IV-7 VERTICAL STANDARD DEVIATIONS OF A PLUME. The vertical standard deviations corresponding to those in (IV-6) are shown. The stable plots approach constant values beyond 10,000 m. It is believed that vertical dispersion almost ceases in such conditions, provided there are no breakdowns of the stable layer by strong wind shears. As before, the curves are tentative beyond 10,000 m.


% Panel Response
100%
80%
60%
40%
20%
0%
10
8
6
4
2
0
Annoyance
1
10
100
1000
Micrograms per m3
Detection
Complaint
Annoyance

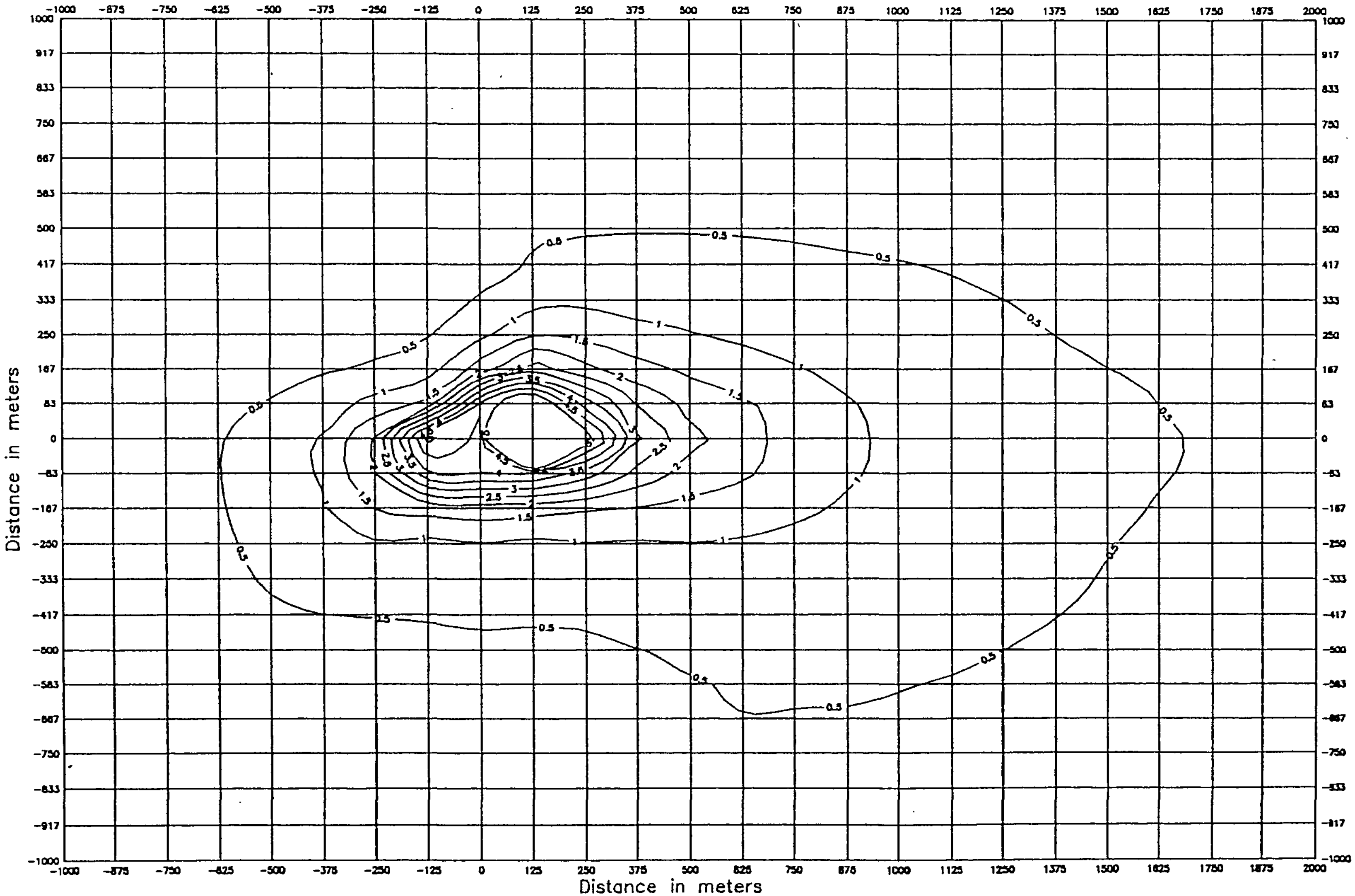


Annual Windrose for Achella

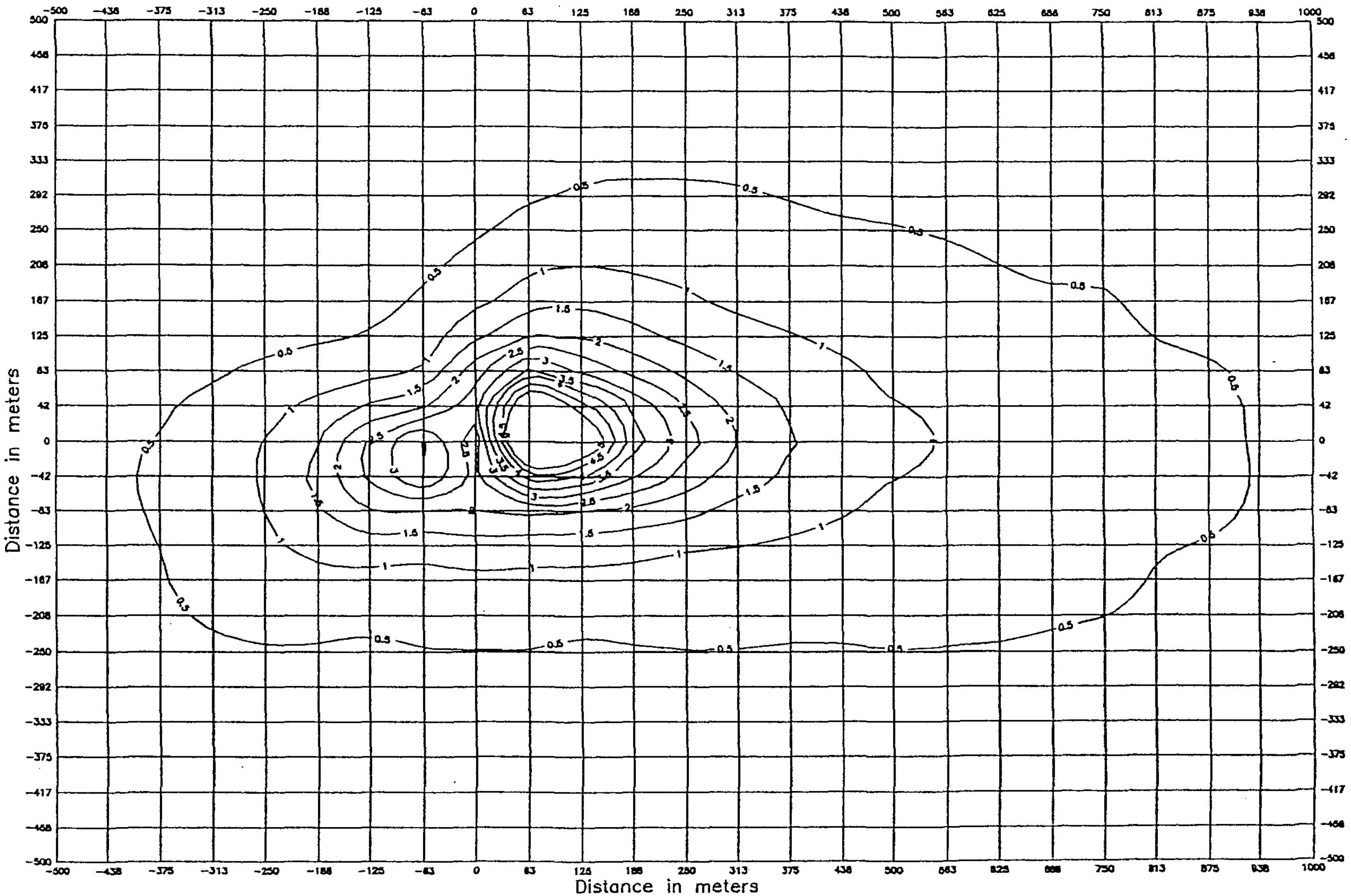


Annual Windrose for Paphos Airport

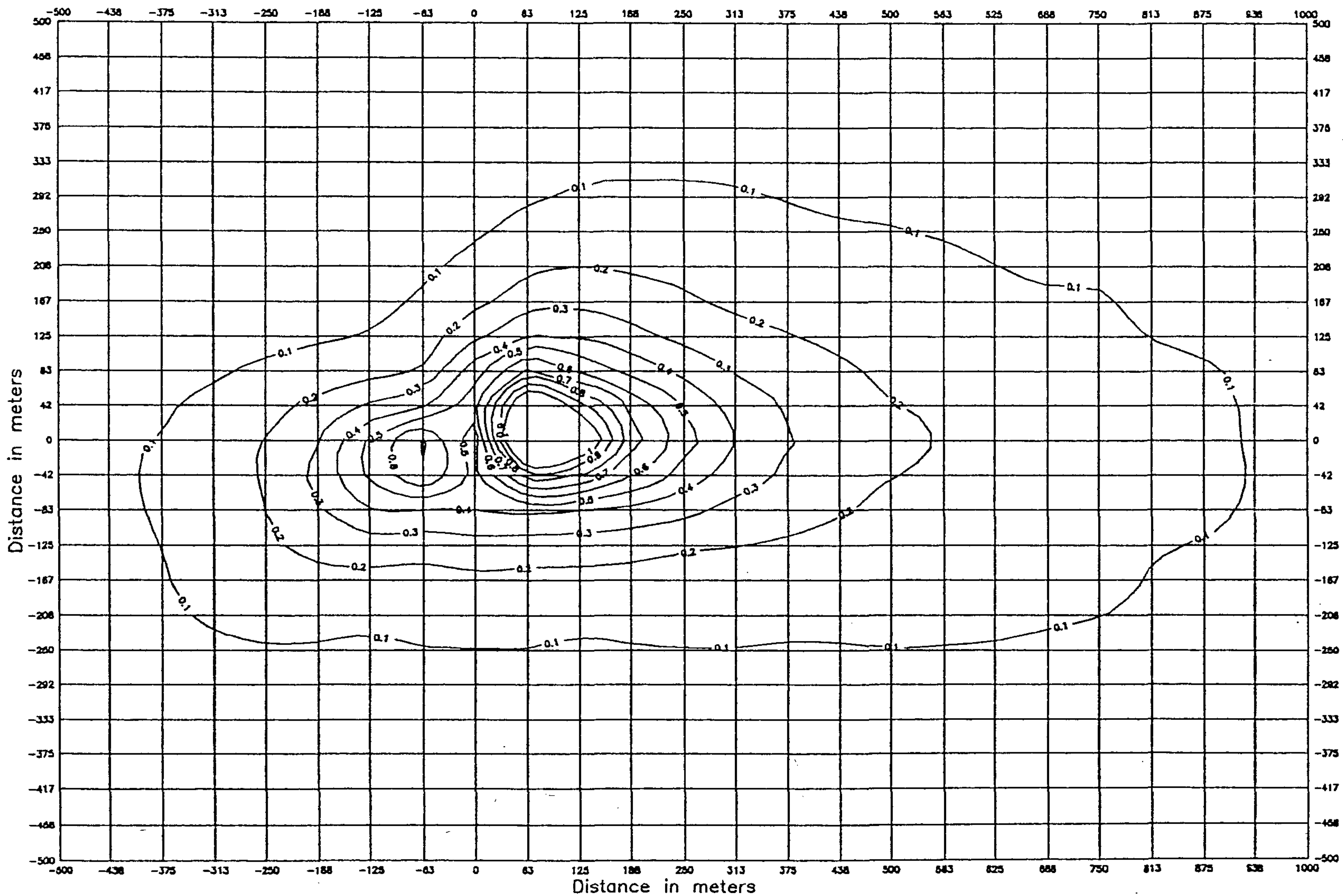
PAPHOS SEWAGE TREATMENT PLANT



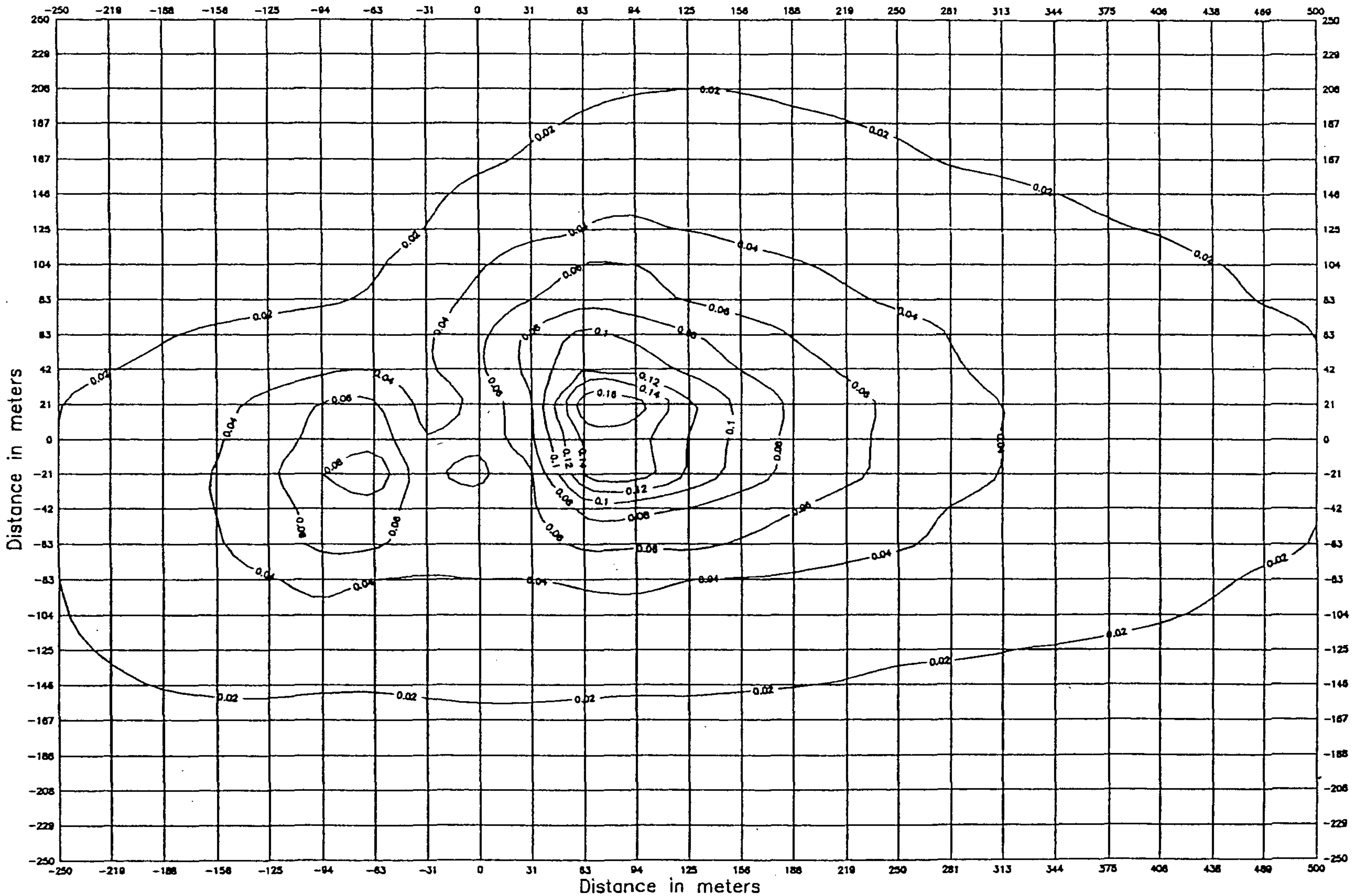
PAPHOS SEWAGE TREATMENT PLANT



PAPHOS SEWAGE TREATMENT PLANT



PAPHOS SEWAGE TREATMENT PLANT



3.0 MITIGATION MEASURES

3.1 Odour control at STP's

The treatment option selected by the SBP is conventional activated sludge. Sewage will enter the treatment works via screening and grit removal stages. The sewage will then pass to primary settlement tanks, before receiving secondary treatment by activated sludge plant. After secondary settlement, the effluent will be chlorinated, treated with coagulants, resettled and sand filtered.

In sewage treatment operations such as the above, the potential for a significant degree of environmental impact inevitably exists. Good practices in design and operation will limit this impact to an acceptable level. It is at the design stage that many of the potential impacts can be foreseen and minimised. The following sections summarise the positive and negative impacts of the project.

Positive Environmental Impacts

- The recovery of approximately 20000 m^3/day of high quality treated wastewater.
- Potential enhancement of the local environment, by use of recovered water for irrigation of recreational areas.
- Increased availability of water for irrigation of crops/plants.
- Protection of groundwater sources from organic and bacterial contamination.
- Reduced noise and traffic disturbance from septage tankering.
- Aleviation of odour problems from existing septic tanks.
- General improvement in sanitary conditions.
- The production of sewage sludge as a valuable fertiliser and soil conditioner.
- Improved compliance with EU environmental directives.

Indirect positive impacts include:

- the provision of serviced sites for development
- increased tourist and recreational activity and revenues
- increased agricultural and silvicultural productivity and/or reduced chemical fertilizer requirements if treated effluent and sludge are reused, and
- reduced demands on other water sources as a result of effluent reuse.
- increased water availability to support development in the region
- the opportunity to diminish irrigation demands on potential public water supply sources
- reduced need for chemical fertilizers

- incremental improvements in crop and timber production, and
- low-cost means to re-vegetate marginal soils or reclaim them for agriculture or silviculture

A number of these potential positive impacts lend themselves to measurement and thus can be incorporated quantitatively into analyses of the costs and benefits of various alternatives when planning wastewater projects at the National Economy level.

Negative Environmental Impacts

Wastewater projects are executed in order to prevent or alleviate the effects of pollutants on the human and natural environments. When properly carried out, their overall environmental impact is positive. In addition, installation of a wastewater collection and treatment systems provides an opportunity for more effective control of industrial wastewater through pretreatment and connection to public sewers and offers the potential for beneficial reuse of treated effluent and sludge therefore as a rule wastewater collection and treatment do not have negative impacts if well planned and operated.

Odour abatement technology for sewage treatment plants is available and begins with the recognition that first and foremost the odorous gases must be contained. This of course is in addition of any measures taken to prevent the formation and release of odourous compounds to begin with. It must also be recognised that odours are not only caused by H_2S, which is most often mentioned, but also by other compounds.

Engineers engaged in the odour abatement field recognise what H_2S can be mitigated by one set of measures where as NH_3 and other compounds are best deat with by another set of measures.

The following technologies are available:

- Scrubbing (including twin systems and systems containing chemicals such as hypochlorite, ozone etc).
- Biofiltration
- Activated carbon absorption
- UV irradiation

The most appropriate technology depends on the amount of gas that needs to be treated, the available land and a number of other factors.

In the case of sewage treatment plants the amount of gas to be treated is dependent on the particular aeration technology selected and whether the design allows the collection of the odourous gases.

A further mitigation measure is the observance of certain buffer distances recommended by the experience of other countries. Good site layout therefore is a good starting point for odour control. Potential odour producing activities should be placed at the centre of the site if there is no adequate area to allow a generous buffer zone between equipment and perimeter. The SBP layout puts the potentially odorous processes at the centre of the site at a distance of 150 m from the site boundaries.

Table 3.1 gives suggested buffer distances.

TABLE 3.1

Suggested minimum buffer distances from treatment units for odour containment[1,2]

Treatment process unit	Buffer distance ft[3]
Sedimentation tank	400
Trickling filter	400
Aeration tank	500
Aerated lagoon	1,000
Sludge digester (aerobic or anaerobic)	500
Sludge-handling units	
Open drying beds	500
Cover drying beds	400
Sludge-holding tank	1,000
Sludge-thickening tank	1,000
Vacuum filter	500
Wet-air oxidation	1,500
Effluent recharge bed	800
Secondary effluent filters	
Open	500
Enclosed	200
Advanced wastewater treatment	
Tertiary effluent filters	
Open	300
Enclosed	200
Denitrification	300
Polishing lagoon	500
Land disposal	500

1 Source: New York State Department of Environmental Conservation.
2 Actual buffer distance requirements depend upon a number of conditions
3 Note: ft x 0.3048 = m

3.2 Odour control at PS's

The four main environmental issues for pumping stations are:

- Odour
- Noise
- Aesthetics
- Removal of dirt when cleaned and serviced

The issues of odour can be adequately dealt with. Activated carbon filters can be used quite effectively. Alternative systems using UV radiation are also available.

The issue of noise can be adequately dealt with by proper design and installation and the use low noise equipment. Stand-by generators can be fitted with appropriate silencers but in any case their use is only an emergency stand-by measure as most of the time they will be on stand-by. Alternatively stand-by generators can be trailer mounted and rushed to each PS in case of an emergency.

The question of aesthetics is mostly a policy decision because it will affect cost. For each particular location there should be a design which apart from satisfying operational requirements it should also meet the appropriate aesthetic criterion.

This aesthetic criterion is none other than the ability of the architectural design to "disguise" the pumping station with the most appropriate external appearance.

Thus a pumping station may on the outside look like:

- A house
- A shop
- A farmhouse
- A garage
- Etc

The following photograph shows an entire STP disguised as a farmhouse. Something similar but on a smaller scale can be done for the pumping stations.

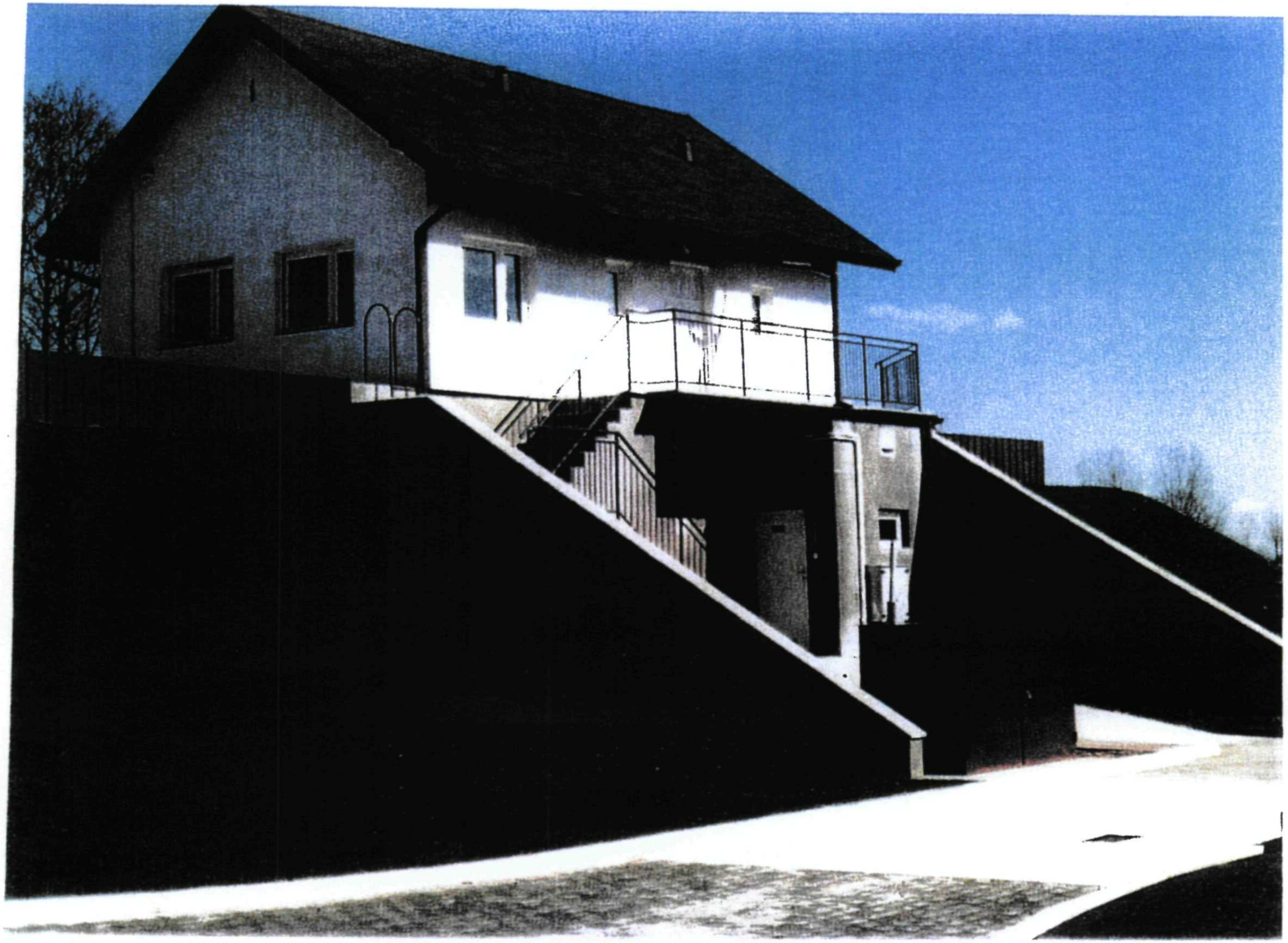
Two types of devices can effect odour control at pumping stations:

1. Biofilters - when there is space
2. Activated carbon filters

Both types of units are discussed further in Appendix IV.

With regard to the pumping stations in the Pafos scheme.

PSA can best be served by a biofilter



PSB can best be served by an activated carbon filter on the roof of the building

PSKP can be served by an appropriate device to fit its design

To further reduce odours at the pumping stations, all piping, sumps and pumps must be enclosed or submerged as needed. All escaping gases must be through the filtered vents. A slight negative pressure must be maintained in order to further reduce the possibility of odour escaping.

At the treatment head-works (Already decided to be enclosed)

- ➢ Design of building to maintain slight negative air pressure by a twin system (one blower on plus one on stand-by).
- ➢ Collection of preaeration off-gas and ducting to twin tower scrubbing system

3.3 Other issues

Health and Safety

Safety

Issues can be subdivided into:
- Chlorine hazards
- Biogas hazards
- Hazards of working near open ponds, especially with bubble aeration or/rotors
- Hazards from working in confined spaces (ie sewers)
- Hazards from working with machinery (mechanical, electrical, hand tools etc).

All the above are well known and they have been extensively studied. There are guidelines and instructions regarding all of them. In general however the following points must be taken care of in design so that problems are avoided later on.

- Public health
    - Avoid operations generating sprays and dust
    - Avoid operations requiring physical contract with raw sewage liquids or solids
    - Avoid situations where H_2S may be inhaled
    - Provide for frequent personnel medical check-ups
    - Adhere to published guidelines with regard to sludge and effluent reuse.

- Safety
  - Design according to established safety codes
  - Provide for good ventilation
  - Provide for explosion relief anywhere biogas is likely to be present
  - Provide adequate safeguards, safety equipment and alarm systems (particularly sensors and alarms for H_2S, CH_4, Cl_2)
  - Provide for continuous personnel training, including practice drills.

Noise

The issue of noise is related to

- Construction of the collection system and the STP's
- Operation of the STP's
- Operation of the PS's

With regard to construction, the levels of noise to be anticipated are circa 92 – 95 dBA at 5m and the generation of noise, the acceptable limits and the techniques for measuring these, are the subject of numerous international standards. In Cyprus there are no standards for noise yet. However the appropriate authority (Ministry of Labour) is using the European limits as a guide.

Construction activity noise can be somewhat regulated through the contract with the contractors but as the activity is in any way temporary not much can be stipulated other than the use (where possible) of low noise compressors, engines and equipment.

With regard to the operation of the STP's their isolated location is in itself a noise mitigation measure. However noise levels of the order of 65-70, dBA may be expected near equipment such as rotors, compressors and motors. Noise is a particular nuisance at night when background noise levels are low. The standard advise for reducing noise is:

- Avoid excessive vibrations
- Isolate vibrations
- Provide solid barriers between source and receptor

The use of low noise equipment, in an enclosed and sound-proofed engine-room will is a form of a generalized instruction to all designers of plant.

Measurements taken at much noisier installations such as crashing plants show that at distances of the order recommended for STP equipment "isolation" (see table 3.1), noise levels can indeed be quite low (of the order of 55-60 dBA). It should be noted here that the noise level drops by 6 dBA for every doubling of the distance.

Noise at pumping stations is a rather more serious issue as these will be mostly in residential areas. Experience shows that with carefull design normal PS operation does not produce any noticeable noise beyond the perimeter. PS as a rule work intermittently, activated by level controls and depending on the specific position in the system and their geographical location, this may be more frequent during peak hours which are not times during which most people are at sleep. The exceptional case of the stand-by generator coming on, either for testing or to cover an emergency, can be provided by good engine silencing and exhaust design.

Field personnel must recognize that tanks containing septic wastewater may contain lethal gases. Designs should be such that prolonged exposure of workmen to the gases is unnecessary and discouraged.

While H_2S is heavier than air, in septic tanks it may be drafted away by the much larger volume of methane. Ventilation accomplished through the roof vent of the home . At locations where sewer gases are ventilated at air release valves on the main, odours may become a source of complaint if the air release valve is located near an inhabited area. In that case the gases may be vented to a soil bed for odour absorption.

Another consideration that must be addressed is corrosion. In pressure sewer pump vaults, plastics are preferred because of their corrosion resistance. Austenitic stainless steels, specifically Type 316 and Type 304, can also be used and are unaffected by corrosion.

When ventilated in the usual way, a septic tank atmosphere differs little from normal air. When not ventilated, the methane is too rich for combustion and the hydrogen sulphide too lean. Danger of fire or explosion would be greatest in this situation with the right degree of imperfect ventilation.

If the tank is ventilated through the roof vent and the pressure sewer pump is submerged, the likelihood of ignition is minimized. Installations must comply with safety requirements with regard to the hazardous condition potentially present.

If a sewer main conveys septic wastewater discharges to a conventional gravity sewer, corrosion of the receiving sewer and manhole is to be expected. Pretreatment is advised, by chlorine, air injection, or other methods.

Emergency pond

The plans provide for the construction of an emergency pond for the retention of raw sewage for one day to cover emergencies. Such a pond since it will no be covered or aerated it must be shallow (of the order of 1.0 depth) to allow for natural aeration. In the event that the emergency pond is used if will fill quickly, within a day, but will be emptied showily, within the course of a few days. It is recommended that the pond by of such construction as to allow its flushing and cleaning after use and to allow for easy removal of wind blow debris (leaves, etc).

If the bond is made of concrete then its sides and hosing can easily clean bottom so that remains do not cause odours or attract flies. It is further recommended that the pond floor have at least a 2° slope towards the outlet.

3.4 Summary of recommendations

1. Choice of aeration system

It is recommended that the aeration system employed for the Pafos STP is that of fine bubble aeration, for the following reasons.

- Less power consumption
- Air intake at distance from oxidation basins allowing future options for
  - Oxygen enrichment
  - Covering of oxidation basins, if needed
  - Collecting and treating exhaust air/gas, if needed.
- No sprays formed
- Much easier to take noise control measures
- More uniform oxidation

In addition there is the possibility for increased system reliability if designed with this in mind. (i.e. multiple small circuits, with more than the standard number of compressors.

2. Odour control measures recommended in the DFDR – June 1998 but not specified in detail are:

- odour control equipment for all preliminary and sludge treatment works
- Odour control equipment at the PS
- Twin pipe force mains (where appropriate)
- Odour control units at the force mains outlet manholes

Specific odour control measures included in the proposed design are the prechlorination of raw incoming sewage; aeration of the grit chamber; aeration in the activated sludge biological reactor, and addition of disinfectant in the chlorine contact chamber.

The sludge thickener is to be covered and vented. The air vented from this structure will be scrubbed to remove the odour before release to the atmosphere. The sludge dewatering process will be enclosed in a building and the air vented from it will undergo odour control.

In addition it should be reminded here that the Ministerial Committee decision requires that all preliminary (headworks) treatment activities should be covered.

4.0 SEPTAGE TREATMENT

4.1 Properties of Septage

Septic tanks must be pumped out at regular intervals and the mixture of sludge and supernatant removed is defined as ***septage***. Pumping frequencies vary but for efficient septic-tank operation the time interval between pumping out is usually not greater than 1-4 years. Septage accumulation is reported to be about 250l/hd per year in the USA and 200 l/hd per year in Canada. In the UK a value of 136 l/hd per year is often adopted, in accordance with British Standard Code of Practice CP 302, but in practice the actual rate may be less as shown by the following example:

Sewage flow	120 l/hd d
Sewage SS	350mg/l
SS removal	70%
Solids destroyed by digestion	0.029 kg/hd d
Sludge build-up	30%
Sludge dry solids	0.02 kg/hd d
Sludge build-up	9%
	0.22 l/hd d
	83 l/hd per year

A typical effluent from a two-compartment tank in the UK will contain about 250 mg/l BOD, 125 mg/l SS and 1-2 million faecal coliforms/100 ml, representing average BOD and SS removal rates of 45 and 80% respectively according to Mann. Similar efficiencies are reported for septic tanks in the USA.

The characteristics of septage vary and are influenced by the frequency of desludging. Average concentrations of BOD and SS in septage in the USA are reported by the Environmental Protection Agency to be 5000 mg/l and 15 000 mg/l respectively, but the values reported varied from 440 to 78 600 mg/l for BOD and from 310 to 93 400 mg/l for SS. Results of another survey of USA septage show mean BOD and SS values of 4790 mg/l and 2350 mg/l respectively. In Canada the mean BOD concentration of septage was shown by one study to be 5350 mg/l,almost identical to that reported in the USA. The data in Table 4.1 give typical values of septage characteristics in the USA and Canada; in the case of the Canadian survey information is included on septic-tank sludge and septic-tank supernatant.

Table 4.1
Septage Characteristics in USA and Canada

Parameter (mg/l)	USA* septage	Canada†		
		Septage	Sludge	Super-natant
.pH	6.0-9.0	6.2-8.7	-	7.2 – 7.7
Total solids	40 000	15 500	30 767	1498
SS	15 000	-	-	436
BOD	5 000	5351	10 500	223
COD	45 000	15470	27 800	870
Amm. N	150	64	51	75
NO_2 (as N)	0.21	0.07	0.01	0.03
NO_3 (as N)	0.72	0.28	0.1	0.21
Soluble P	21	13.7	19.4	6.7
Chloride	-	100	95	120
Total coliform (/100ml)	-	4.6×10^6	44.7×10^6	2.25×10^6
Faecal coliform (100/ml)	-	2.7×10^6	5.2×10^6	0.99×10^6

*Mean values from Environmental Protection Agency.
†Mean values from Brandes, sludge and supernatant data for first compartment of two-compartment tanks desludged at an interval of four years.

It is common practice to discharge only WC wastes to the septic tank, the effluent passing to an absorption pit in the case of houses or to a holding tank in the case of multi-story dwellings. Wastes from other domestic water uses (sullage) are discharged direct to the absorption pit or holding tank after first passing through a grease trap.

Problems occur with the absorption pits and in many areas it is necessary to pump out the pits at regular intervals. Problems arise when pits are constructed in unsuitable ground, particularly clays, or if the pits are constructed in suitable ground underlain by clay, a practice which gives rise to seepage occurring along exposed clay boundaries. In many cases capacity of the ground is exceeded. The situation is exacerbated by the non–treatment of sullage which places a heavier burden of organic matter and grease on the absorption pit that would otherwise be the case.

The septic tanks used in Cyprus are similar to those recommended in the UK, and tank capacities for a range of populations are shown in Table 4.2.

Table 4.2
Septic-Tank Capacities (m^3)

Population	Nicosia			UK†
	Municipality	District*		
		House	Flat	
10	2.4	3.0	2.0	3.8
20	3.7	6.0	4.0	5.6
30	6.0	9.0	6.0	7.4
40	7.4	12.0	8.0	9.2
70	12.6	21.0	14.0	14.6
100	14.7	30.0	20.0	20.0
150	20.6	45.0	30.0	29.0

* House tank based on 300 l/hd and desludging every two years.
Flat tank based on 200 l/hd and desludging every year.

† From British Standards Institution, recommended desludging every year.

Septage Quantities

The volume of septage removed by tankers in Pafos is about ***500 m^3/d***. This quantity is carried by tanker tracks with a mean capacity of about 7 m^3 making several trips each day to the disposal area. Septage quantities are virtually constant throughout the year. Apeak may occur in spring when householders become aware of seepage from absorption pits after the groundwater has receded and the ground has dried out.

The septage volume from a survey in Nicosia was equivalent to 6.3 l/hd d. Surveys carried out in two other towns in Cyprus, namely Limassol and Larnaca with populations of 110 000 and 40 000 respectively, showed septage volumes to be 6.0 and 13.5 l/hd d. The high volume in Larnaca resulted from half the population of the town residing in an area where the ground was essentially a mixture of gravels, sand and shingle with groundwater at a depth of 1.5-2.0 m.

Septage Quality Characteristics

Samples of septage collected from a number of septic tanks, holding tanks, absorption pits and tankers and the analytical results are presented in Table 4.3 and 4.4. These figures were obtained by R.M. Bradley in a survey for Nicosia in 1978.

Composite samples were collected from tankers at the time of discharge at the disposal area. Grab samples were taken from three house septic tanks and absorption pits and from three house septic tanks and absorption pits and from three medium-rise building septic tanks and holding tanks. The second compartment of the septic tank was sampled in each case above the sludge layer.

It is apparent that septage in Nicosia has characteristics similar to septic-tank supernatant elsewhere, rather than to septage, as shown in Table 4.5. Since the Nicosia tanks are pumped out in order to relieve hydraulic ponding and not to remove sludge, as in conventional septic-tank operation, the waste is naturally weaker. The log mean BOD from Table 4.3 is 305 mg/l, ignoring the tanker discharge sample containing laundry waste.

The mean total nitrogen (org.N plus amm.N) and total phosphorus concentrations of 146 mg/l and 8.2 mg/l respectively are equivalent to 18 g N/hd d and 1.0 g P/hd d. Although the phosphorus level is typical for crude sewage, the nitrogen content is double the typical value in crude sewage of 9-11 g N/hd d. The mean concentration of amm.N of 178 mg/l is similar to that normally recorded in digested sludge supernatant (140-270 mg/l).

The metal concentrations in Nicosia septage are compared in Table 4.4 with those in UK sewage and USA sewage and septage. The boron concentration of 1.01 mg/l can be compared with a typical Nicosia water supply level of 0.41 mg/l. Salmonellae organisms were isolated from only one sample, an absorption pit containing 100 Salmonellae/100 ml. Ova ranging 15-30/100 ml were isolated in five samples, although none of the ova were pathogenic to humans.

It is possible to calculate the BOD loads in WC waste and sullage in Pafos using the data in Table 4.3, assuming a sewage flow of 114 l/hd d of which sullage would represent 67%.

Total sewage flow	= 114 l/hd d
WC	= 38 l/hd d
Sullage	= 76 l/hd d
Absorption pit / holding tank BOD	= 344 mg/l
Septic tank BOD	= 332 mg/l
Sullage BOD x 76 l	= BOD (344x114)l - BOD (332x38)l
Sullage BOD	= 350 mg/l

Assume BOD reduction in septic tank is 40%, hence WC BOD=553 mg/l. Mixed Pafos sewage (WC+sullage) would, therefore, be expected to have a BOD of 418 mg/l equivalent to 48 g BOD/hd d. The BOD load in the sullage is equivalent to 27 g/hd d.

Sullage in the USA generally has characteristics as shown in Table 4.5. The suggested design flow of 130 l/hd d is based on 60% total waste flow increased by a factor of 1.5 to account for peaks. Average pollution loads from rural households in the USA are summarized as 39 g BOD/hd d and 23 g SS/hs d, of which automatic dishwashers account for 33 and 23% of the BOD and SS load respectively. If garbage-disposal units are installed the total sullage loads should be increased by 11 g BOD/hd d and 16 g BOD/hd d. From Table 4.5 the average BOD and SS loads are 22 and 17 g/hd d respectively, almost identical to the figures for sullage excluding automatic dishwashers and garbage-disposal units. The BOD load of 27 g/hd d in Nicosia sullage is similar to the USA value.

TABLE 4.3
SEPTAGE CHARACTERISTICS IN NICOSIA

Parameter (mg/1)	Septic tanks House	Septic tanks Flat	Absorption pits (flat)	Holding tanks (flat)	Tankers†
pH	7.3	7.1	7.3	7.1	7.2 – 9.00
Total solids	2969	1698	2853	1713	4266 (2123)
SS	1256	297	1688	255	773
VS (%SS)	74	85	64	86	62
BOD*	418	264	454	260	334 (203)
COD	1820	857	1750	910	1488 (940)
PV	191	91	197	91	109 (81)
Org.N	27	11.8	30	16.4	7
Amm.N	293	94	247	91	139
PO_4	8.3	7.5	8.2	7.6	8.2
Chloride	-	-	-	-	1414 (422)
Faecal Coliform (/100 ml)	6.8×10^6	26.5×10^6	5.7×10^6	28.7×10^6	9.2×10^6

*Log mean values, all other values are arithmetic means.
†Means influenced by one tanker containing, suspected laundry waste. Figures in parentheses are means omitting samples containing laundry waste.

TABLE 4.4
METAL CONTENT OF SEPTAGE AND CRUDE SEWAGE

Metal (mg/l)	Nicosia septage	USA septage	UK sewage	USA sewage
B	1.01	-	1.0-3.0	-
Cd	0.164*	0.5	0.005	0.004-0.014
Zn	0.89	50	0.9	0.03-8.31
Ni	0.38	1.0	0.2	0.002-0.105
Cu	0.08	8.5	0.6	0.02-3.6

*High value, analyses suspect.

TABLE 4.5
POLLUTION CHARACTERISTICS OF SULLAGE IN USA

Parameters	Typical range	Suggested design value
Flow (l/hd d)	130-170	130
BOD (mg/l)	100-300	250
SS (mg/l)	85-300	200
Total N (mg/l)	3-25	15
PO_4(mg/l)	8-95	50
Grease (mg/l)	60-150	130
Temperature (^{0}C)	40-60	50
Total coli (No./100 ml)	-	$25x10^3$

The mean annual domestic water consumption is circa 120-130 l/hd d which, on the basis of a summer /winter ratio of 1.38, produced summer and winter consumptions of 157 and 114 l/hd d, respectively. During the summer it was estimated that 25% of the consumption was used for garden irrigation, hence sewage flows in Nicosia were estimated to be about 114 l/hd d in winter and 118 l/hd d in summer. Although some houses had private wells the groundwater was polluted (typical nitrate concentration 75 mg/ l NO_3) and well water was restricted to garden use. Automatic washing machines were reasonably widespread, dishwashers were rate and garbage grinders were almost non-existent.

The estimated domestic, sewage flow in Nicosia of 114-118 l/hd d is similar to the household water consumption in Western Europe, as show in Table 4.6. The proportion of household wastewater represented by sullage varies and is related to water use within the household. In Western Europe the sullage is likely to constitute 66-75% of the total. In the USA and Canada sullage generally accounts for 40-70% of the total wastewater flow, with 60% being typical. According to Stoner the general USA sullage generation rate of 57-190l/hd d can be reduced to 47-70l/hd d if water conservation is practised.

Because of the similarities in living standards and household water use patterns between Nicosia and Western Europe, a value of 67% total sewage flow was assumed to constitute sullage in Nicosia.

TABLE 4.6
HOUSEHOLD WATER USE IN WESTERN EUROPE AND USA.

Component	Water use (l/hd d)			
	UK*	Belgium+	West Germany+	USA∇
WC	37	42	30	80
Kitchen, cooking, dishwashing	29	15	16	15
Personal washing ..	28	38	42	50
Laundry ..	13	11	30	38
Miscellaneous ..	3	22	-	6
Total	110	128	118	189
Sullage (%total) ..	66	67	75	58

*From Rump
+From Males
∇From Ligman

4.2 Treatment of Septage

Septage can best be treated together with the rest of sewage pumped to the STP. Preaeration and degriting will be necessary as tanker contents contain considerable amounts of silt and grit.

The septage will be dosed continuously at the proportion prescribed by the design quantities, to the main sewage flow as it enters the pre-treatment section.

These must be provision for chemical (ozone) pre-treatment of septage if practice shows that the "refractory organics" accumulating in it are not removed by the conventional STP process.

The heavy metal content of septage might lead to increased levels of toxic metal in the sludge so the analyses of sludge must be carefully monitored as per the European Directive (96/289/EEC).

Septage reception must be provided for in an enclosed station fitted with air curtains, activated carbon odour control and a pressurized, chlorinated, water supply to allow the operation of vehicle tank CIP systems and truck cleaning.

A new, temporary septage reception and treatment system is to be installed at the site of the new Pafos landfill. When the Pafos STP is ready to receive sewage for treatment it will also be able to receive septage. As more residences are connected the amount of septage will be decreasing but it is not anticipated that is will cease to be an input into the STP. The availability of the temporary reception and treatment system at the landfill permits great flexibility in controlling the ratio of fresh sewage to septage that enters the STP for co-treatment.

4.3 Operating standards for vehicles / tankers

The operation of tanker trucks is specified by the Road Transport Department, which issues the permits for such special vehicles.

The vehicles are inspected for:

➢ Having a screw cap on the tank valves to prevent dripping. Traffic police also checks this on a routine basis.

➢ Having covered storage compartments for hoses at the sides, or elsewhere, of the tank. This is checked at the annual inspection of the vehicle before license renewal

➢ Having a "Jelly stick" at the pump exit, for odour control (Note: Officers at the Road Transport Department could not give details. This is presumably a proprietary name of what might be a hypochlorite jelly used for odour control)

In addition to the obligations of the owners and operators of such vehicles which emanate from the laws and the conditions of the license, the following must also constitute part of the SBP scheme which will be the recipient of the liquids collected by the tankers.

Tankers may be used for the abstraction of:

- Septage
- Raw sewage
- Industrial waste
- Flood waters

The following points should be made part of special regulations:

- Tankers must have drip-proof valves. Dripping while in motion on public roads is an offence.

- Tankers must install CIP (Clean-in-place) systems to allow the washing of their tanks and hoses at the septage reception station.

- Tankers must work within the normal working hours of the STP and they must respect the public working hours and hours of common peace.

- Tankers must obey standard noise levels by fitting silencers on their vacuum pump outlets.

- Manholes must be covered by simple, appropriate means to prevent odours from escaping when tankers are servicing septic tanks.

- Tankers must be fitted with odour filter units at the exist of any pipe to the atmosphere.

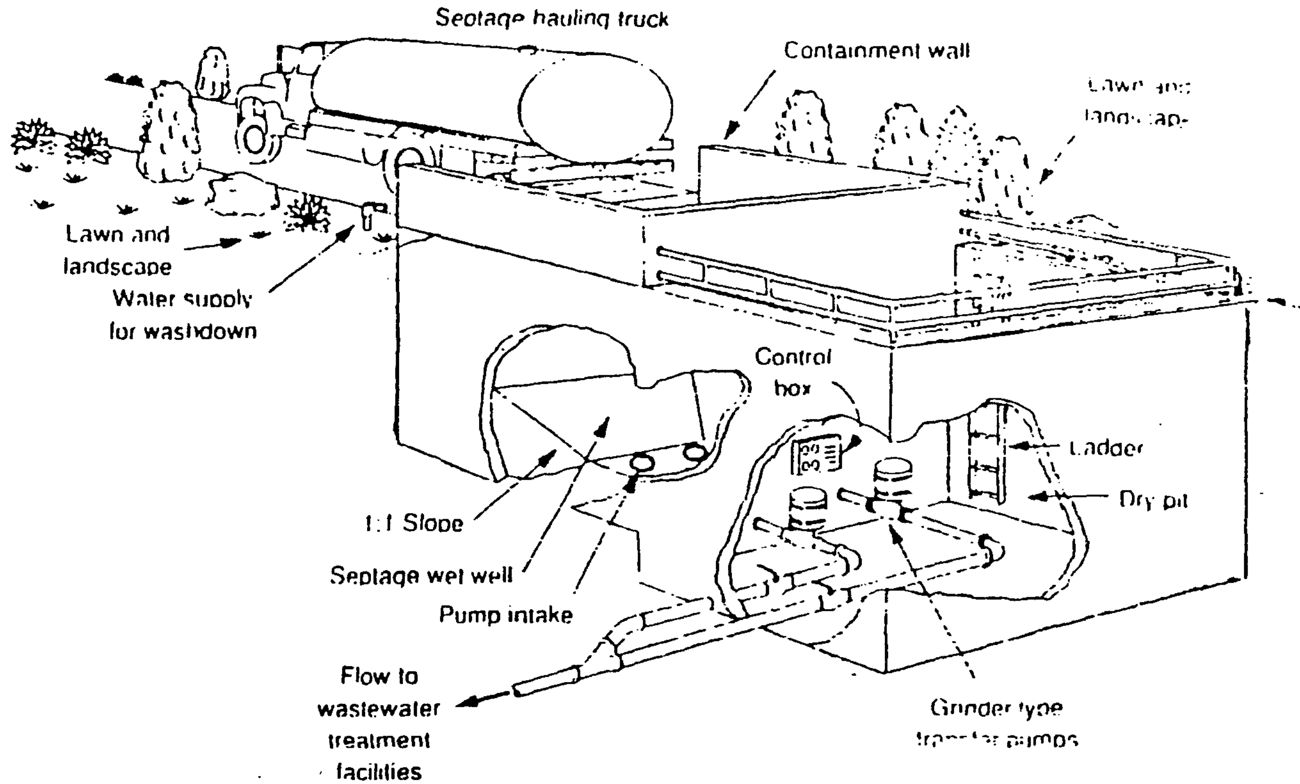
- Tankers must be fitted with a 75-100 litre tank with a tap to carry clean water for washing hands. This is for operator and public health protection.

- Tankers must carry a supply of disinfecting hand soap supply of grease in order to reseal manholes which have been opened for any reason.

- The tankers must not carry mixed loads without declaring this to the septage reception station. This should be particularly enforced with industrial effluent and oil bearing waste.

- The SBP must proceed as soon as possible with the registration of all possible industrial sources and the characterization of their effluents. This may call for a separate specialized survey.

There is no reason why vehicle appearance cannot be more elegant. After all fire fighting vehicles are also tankers with special features and they look so much neater than septage tankers.



Typical septage receiving station located at a wastewater treatment plant.

4.4 Odour prevention measures from tankers

4.4.1 Tanker washing

Tanker washing may be easily effected by the installation on each licensed tanker of 1-2 special CIP balls (see figure 4.1). This will be connected to a pressure wash system at the septage reception station and will allow the wash of the inside of the tank.

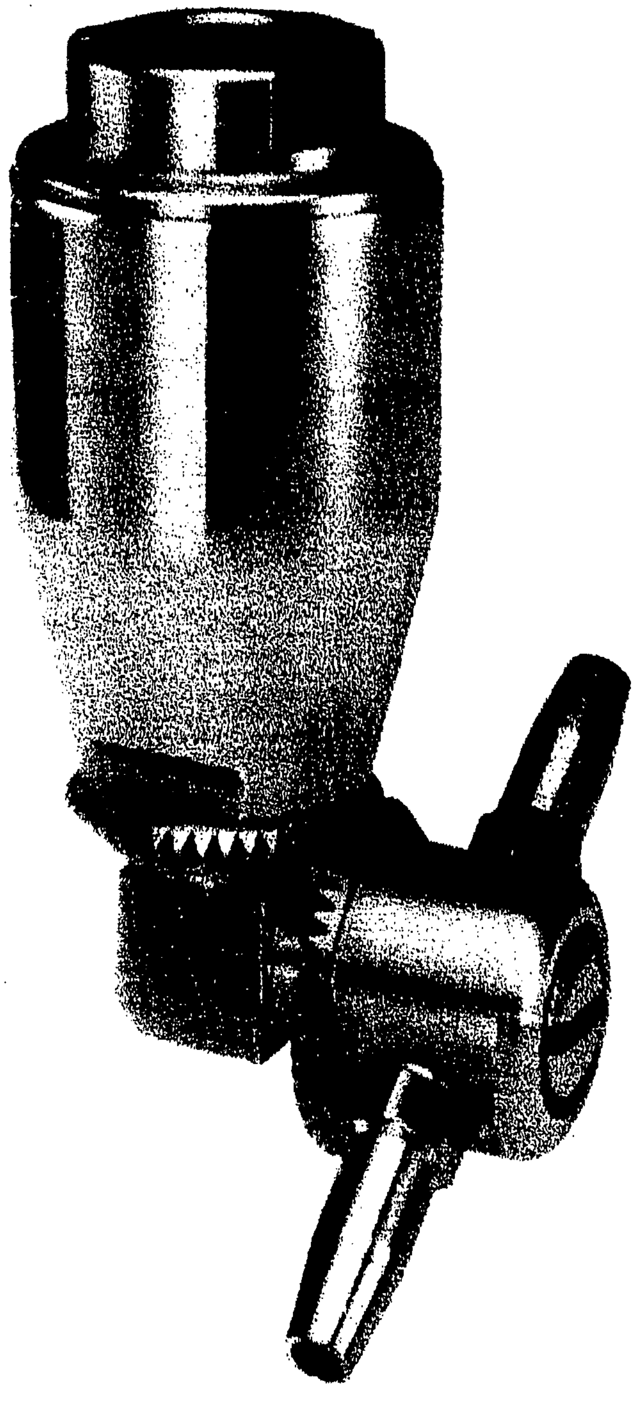
Tank washings will return to the septage reception tanks of the Pafos STP. After tank washing the hoses and the washing water connection will be disconnected and the washed tanker will be cleared for return to further service.

4.4.2 On-board filters

On-board odour control units for tankers consist of small activated carbon canisters, which are, either replaced or regenerated when exhausted. They are very good for H_2S and other odours found in septic tanks.

The SBP can offer a filter regeneration service as part of its total service to the town and the tanker owner/operators. A small filter regeneration unit may be operated at the STP with very little or no charge to the tanker drivers.

Figure 4.1
CIP balls



5.0 SLUDGE TREATMENT AND DISPOSAL

Sludge production

Dry weight per capita production of sewage sludge resulting from primary and secondary treatment is about 90 grams per day per person, which is more or less the same in all EU countries where municipal communities are served by two stage physical, mechanical and biological processing plants.

In some European countries the main practice is landfilling (50to75%), while the rest is disposed in agricultural fields as soil conditioner/ fertiliser (25 to 35%) or other recycling outlets (e.g. parks, land restoration and landscaping).

Agricultural use of raw sludge or other composting practices is encouraged by national authorities as the best way for recycling, while incineration is considered the worst. Directive 86/278/EEC on Sewage Sludge in agriculture requires, however, that no-one may permit the use of sewage sludge on agricultural land unless specific requirements are fulfilled. The Directive aims at avoiding the accumulation of toxic substances, especially heavy metals, that might reach excessive levels in the soil after a number of applications.

Sea dumping is now prohibited, and landfilling will also be regulated if the new Landfill Directive is passed and the removal of the organic content is made mandatory. The final disposal of sewage sludge remains therefore an unsolved problem; both because the amount generated will increase and also because agriculture can absorb only a limited number of field applications.

Sewage sludges exhibit wide variations in their properties depending on origin and previous treatment.

For this reason, a vast standardisation activity aiming at defining European standard methods is currently in progress in Europe, under the action called CEN/ TC308/WG1.

Many physical, chemical and biological parameters and tests are available for the characterisation of sewage sludge, thus allowing its behaviour when processed and impact on the environment when disposed/used, to be evaluated.

The purpose of using sludge in agriculture is partly to utilise nutrients such as phosphorus and nitrogen and partly to utilise organic substances for soil improvement.

All Western European countries and the USA have acts or bills on the use of sludge on farmland, but their legislation differs a great deal.

The following requirements are common to these regulations:

- Pre-treatment (reduction of water-content in sludge, reduction of organic substances, reduction of pathogens)
- Restriction on the amount of heavy metals contained in sludge
- Restriction on the amount of dry solids and heavy metals spread per unit of land and time
- Restriction on the content of heavy metals in the soil on which sludge is spread, and requirements for the pH of the soil
- Restriction on the amount of nutrients added to the soil (nitrogen and phosphorus)
- Restriction on the choice of crops
- Restricted access conditions to farmland on which sludge is spread
- Legislative compliance control

5.1 European Union Directives

Human wastes that are not properly treated and are disposed of at the point of origin or are collected and carried away pose risks of parasitic infections (through direct contact with fecal material) and hepatitis and various gastrointestinal diseases including cholera and typhoid (through contamination of water supplies and food). When wastewater is collected but not treated properly before disposal or reuse, the same public health hazards exist at the point of discharge. This also holds for solid waste generated in wastewater treatment (grit, screenings and primary and secondary sludge) which can pollute soil and groundwater if not properly handled. The enforcement of the European Union Directive on sludge addresses this issues by applying the Precautionary Principle.

Cyprus is adapting its legislation to follow the appropriate European Union Directives. Directives relevant to the present case are:

97/C/156/08 On the Landfilling of Waste
86/289/EEC On the land application of sludge
91/271/EEC On urban waste water treatment

Directive 86/289/EEC has already been used to produce the regulations on sludge application mentioned in section 5.3. The Directive requires that biosolids should either be treated before use in agriculture or if untreated they should be incorporated or injected into the soil.

European waste policy is based on a hierarchy of management priorities:

- Minimisation
- Recycling
- Incineration with energy recovery
- Landfilling

The following legislation affects treatment and disposal of waste water sludge.

Urban Waste Water Treatment Directive

(91/271/EEC)
As the directive lays down stricter requirements for wastewater treatment, it leads to a considerable increase in the amount of waste water sludge.

Directive on Protection of the Environment and in particular of the Soil when Waste water sludge is used in Agriculture (86/278/EEC).

This directive concerns the regulations that must be met if sludge is used on farmland. The following requirements are common to these regulations:

- Pre-treatment
- Restriction on the content of heavy metals in sludge
- Restriction on the amount of dry solids and heavy metals spread per unit of land and time
- Restriction on the content of heavy metals in the soil on which sludge is spread, and requirements for the pH of the soil.
- Restriction on the content of micropollutants
- Restriction on the amount of nutrients added to the soil (N and P)
- Restrictions on the choice of crops
- Restricted access conditions to farmland on which sludge is spread
- Legislative compliance control

Draft Directive on Waste Disposal (95/09/15)
Proposal for a Directive on the landfill of waste. The draft directive describes the requirements for design, establishment, operation and close-down of landfills. Landfills must be environmentally approved by the authorities.

The landfilling of waste water sludge is not forbidden, but restricted, as it is biodegradable waste. The target for restriction is to have only 25% of the quantities of biodegradable waste produced in 1993 landfilled in 2010 (Article 5).

Draft Directive on Incineration of Waste (94/08/20)

The draft directive includes waste incineration plants as well as sludge incineration plants and lays down requirements for all emissions from these plants.
One most potentially difficult to implement will be the Directive on the Landfilling of Waste because it has direct reference to sludge disposal. According to this Directive the organic content of waste reaching landfills must be drastically (to 75%) reduced by year 2006, on a nationwide basis and then to 50% by 2009 and to 35% by 2016. The Directive further requires that all wastes must be "subject to treatment" before consignment into a landfill. This means that the following may reasonably be expected to happen.

- Gradual organic diversion from municipal and agroindustrial sources
- Increased use of composting for waste stabilization
- Creation of private solid wastes management systems
- Promotion of RDF (Refuse Derived Fuel) for use in cement kilns
- Promotion of energy from waste schemes
- Restriction of sludge disposal in landfills (The SBP will need to demonstrate compliance to this)

5.2 Some possible solutions for Sludge Disposal / re-use

Wastewater treatment generates sludge and other solid waste, such as grit, and grease screenings. Finding locations for landfill or incineration, or outlets for recycling, is often difficult. However, if solutions are not found, a portion of the pollutants removed from the wastewater will become pollutants of the land. Therefore sludge management should be part of wastewater system planning.

The declining agricultural sector in Cyprus and the shortage of irrigation water make the suggestion of using sludge as a soil conditioner void of substance in some areas. There are many other materials competing for a position in this perceived market opportunity and even more will become available as the full implications of the EU Directive on landfills are realized.

Unless the sewage sludge has any outstanding advantages for the user over competing materials, then its use as a soil conditioner might not be exploited to its full potential.

Suggestion of sludge minimization measures might receive more favourable support. Such measures would be:
- Anaerobic digestion
- Aerobic digestion
- Hydrolysis
- Incineration

Of these the last one requires the drying of sludge which is energy intensive and will need odour control. Of the other, anaerobic digestion produces useful biogas which can be utilized while hydrolysis can either enhance the yield of biogas in anaerobic digestion or pre-treat (retreat sludge) for easier aerobic digestion.

The new EU Directive on the Landfilling of wastes aims amongst others to reduce the amount of organic material going to landfills. When the Directive is enforced in Cyprus all wastewater treatment plants will face a very serious problem. They will not be able to landfill their excess sludge.

The following options are worth considering

- Spreading of undewatered sludge on the ground and applying land farming practices as per the relevant EU Directive (86/278/EEC). This is to be separated from the treated wastewater reuse options. Such a solution will need the dedication of land near the treatment plant where appropriate plantations, machinery and practices will be utilized to dispose of excess sludge and its associated water.

- Spreading and landfarming of dewatered sludge. This is a similar proposal to the one above but will require less land but closer monitoring of soil chemistry so that heavy metals do not accumulate beyond the prescribed limits (see tables at the end of section 5.3). Dewatering will be taken only to the extent where pumpability is maintained. Mechanical dewatering will only add to the cost without offering any real advantage.

- Dewatering the sludge and composting or co-composting it with other organic wastes may be a technical option but in the consultants opinion it cannot be a ret revenue earning operation for the following reasons.

    - There is no evidence that the compost will be readily taken up by farmers especially as the agricultural sector is declining.

    - The very reason that will prevent (prohibit) the landfilling of sludge will create amormous amounts of other organics disposed of by composting. There will be no shortage of compost in the future but rather a shortage of farmers to use it and water to irrigate the crops planted on the soils on which is to be applied.

    - There will be a dependence on farmers who will also bergain for the prices

5.3 Applicable standards

The Provisional Code of Practice for Treated Domestic Sewage Sludge for Agricultural Use makes the following points:

1. The sludge treatment and disinfection plant must be kept and maintained continuously in satisfactory and effective operation so long as the treated sewage sludge is, or is expected, to be used for agricultural purposes or disposed of according to the permits issued.

2. The storage of the treated sludge must not cause environmental problems including risks to public health and pollution of surface and groundwaters.

3. The quality of the treated sludge must be monitored in accordance with a schedule approved by the appropriate authority.

4. Skilled operators must be employed to attend the treatment and disinfection plant, following formal approval by the appropriate authority that the person/s is/are competent to perform the required duties, necessary to ensure that conditions of (i) are satisfied.

   The following domestic sewage sludge treatment methods are acceptable:
   - Anaerobic digestion
   - Aerobic digestion
   - Thermal treatment
   - Storage in shallow lagoons for a period of two years
   - Sludge stabilisation with the use of lime (CaO)
   - Sludge stabilisation after complete biological treatment or extended aeration
   - Drying in specially built spaces (such as sludge drying beds). Storage for a year of the treated sludge
   - Any other method which will be formally approved by the appropriate authority and which method produces a sludge in accordance with the standards for the quality of sludge used for agricultural purposes.

5. The use of the sludge as a soil conditioner is allowed for the following crops:
   - Crops for human consumption, eaten cooked
   - Crops for human consumption, canned
   - Forest plantations
   - Tree plantations
   - Grass for golf courses (l 8 months before planting)
   - Flower beds in parks

6. For the use of sludge for agricultural purposes the following measures must be taken:

There must be control of human movement within the land on which sludge has been used for a period of at least 12 months after application.

- Grazing of animals on land on which sludge has been applied is not allowed for a period of at least 5 weeks after placing the sludge.
- Cultivation of plants yielding fruit to be eaten raw and having no direct contact with the sludge is not allowed for a period of 18 months from the day of placing the sludge.

Collections of any produce, grown on soils conditioned with sludge is not allowed within a period of 3 months from placing the sludge.

The amount of sludge to be placed on a soil shall be determined by the appropriate authority after evaluation of the test resuts for the quantities of heavy metals found in the sludge and in the soil on which the sludge is intended to be used, in accordance with the Standards for Quality of Sludge for Agricultural Use.

7. For the control of the sludge used for agricultural purposes the following programme of analyses is defined:

   Analyses of Sludge: The sludge must be analysed every six months. In cases where variations are observed in the quality of the sewage, the frequency must be adjusted accordingly. These analyses must be for the elements cited in Tables 5.1 and 5.2.

   For comparison the relevant European Standards (Directive 86/278/EEC) are given in Table 5.3.

   Analyses of Soil: The frequency of the analyses will depend on:
   - the initial composition of the soil and its heavy metals content, which must be determined before using the sludge
   - on the heavy metals content
   - of the sludge to be used
   - the frequency of sludge application

8. The following methods of sampling are acceptable:

   For the Sludge: Sampling of the sludge must be carried out after its treatment and before its delivery to the user and it must be representative of the sludge produced.

   For the Soil: Sampling to be done down to a depth of about 20cm below the surface of the soil. Where this is difficult, sampling may be carried out down to 10cm from the surface. Representative sample is that which is being prepared by mixing 5 samples per hectare $x10^{-1}$

9. In order to provide correct management, analyses for N, P, K, Ca, Mg, Fe, B in the soil and the sludge are considered to be useful.

PROVISIONAL QUALITY STANDARDS FOR THE USE OF TREATED DOMESTIC SEWAGE SLUDGE FOR AGRICULTURAL PURPOSES

Table 5.1
Maximum permissible content of heavy metals in the sludge (milligrams per kilogram of dry sludge)

Parameters	Maximum Value (mg/kg)
Cadmium (Cd)	40
Copper (Cu)	1750
Nickel (Ni)	400
Lead (Pb)	1200
Zinc (Hg)	4000
Mercury (Hg)	25
Chromium (Cr)	1000

Table 5.2
Maximum permissible content of heavy metals on the soil (milligrams per kilogram of dry soil)

Parameters	Maximum Value (mg/kg)
Cadmium (Cd)	3
Copper (Cu)	140
Nickel (Ni)	75
Lead (Pb)	300
Zinc (Hg)	300
Mercury (Hg)	1,5
Chromium (Cr)	150

Table 5.3
Limiting values of Heavy Metals as per European Union Directive 86/278/EEC

Metal	Soil mg/kg	Sludge Mg/kg	Dosage rates Kg/ha/yr
Cadmium	1 – 3	20 – 40	0.15
Copper	50 – 140	1000 –1750	12
Nickel	30 – 75	300 – 400	3
Lead	50 – 300	750 – 1200	15
Zinc	150 – 300	2500 –4000	30
Mercury	1 – 1.5	16 – 25	0.1
Chromium	*	**	***

(1) * No EU limit but individual country limits are: Belgium 100 – 150 Spain 100 – 150, France 150, Portugal 50 – 300, UK 400.
** Belgium 500, Spain 1000 – 1500, France 1000 – 2000, Portugal 1000.
*** Belgium 0.5 – 1, Spain 3, France 3, Portugal 4.5.
(2) The range of values is a function of soil type and pH

6.0 TREATED EFFLUENT REUSE

6.1 Introductory comments on Treated Effluent re-use/disposal

The options for the re-use of treated effluent are dictated by its quality, its quantity and the distance from the user. On the latter a single point should suffice to put things into perspective from the point of view of the user. If the same or better quality water can by obtained from a borehole at the site where the water is needed, at a cost lower than Treated Effluent (TE) can be supplied for, then there is no incentive to use treated effluent.

It is therefore imperative to study the reuse options by ranking the National and the user the criteria first.

The most important criterion is water quality. Although there are guidelines for treated wastewater reuse, these do not mention salt content as a parameter. If the total dissolved solids in the water cannot be lowered below circa 1000 ppm there is little point in transporting treated effluent to localities which have adequate ground water supplies with TDS less than 1000ppm (refer to section 4.2.4 of the August 1996 Howard Humpheys / Theophilou EIA report for the Pafos Sewerage and Drainage Project).

The same can be said about those localities that can obtain the water they need at TDS<1000ppm at a cost lower than what SBP will charge.

One could enter into an elaborate feasibility study of comparing the groundwater salinity map with the STP TDS output and then using a cost of distribution and pumping calculation to delineate the area where it would be feasible, under current costs, to distribute treated effluent. Another option is to recharge the effluent to the nearest aquifer of the same salinity. A still further option is to supply irrigation water at the maximum salinity the plants of the area will tolerate.

One of the future studies might then be a groundwater salinity map superimposed on the land use map which also shows the major potential users of treated effluent. Once this is constructed it is a matter of techno-economic feasibility study for each user once the cost of delivering TE to his site is defined. The use of TE will just be another option to be studied by the user of the site.

On the other hand if there are areas where there is no water then TE might be the only option if one wishes to minimize the use of drinking water for non potable uses.

The third option is reuse of TE close to the STP for agricultural production. The increased income (due to the decreased need for fetrilizers) from this might be considered as an indirect subsidy of potable water use for non drinking water needs elsewhere.

6.2 Quantities

The Pafos STP will ultimately produce 20.000 m^3/d of treated waste water. This water will meet the Treated Waste Water Standards of the Ministry of the Interior and the Ministry of Agriculture, Natural Resources and the Environment. The experience of other public and private STP's shows that this is possible with correct design and operating practice.

Local irrigation will require the construction of a separate, in many cases possibly duplicate, system for distribution.

It is the declared policy of the Water Development Department (WDD) not to encourage the creation of new uses for water. Therefore the possibility of irrigating new areas or the creation of new parks must be justified in terms of the area's development.

The possibility of selling TE to the golf courses of Ha-potami should be looked at, especially if it will conserve a potable water supply. It is estimated that these will need on average 3000 m^3 of water per day.

6.3 Provisional Standards for the Re-use of treated effluent and sludge

A national committee has been established to prepare quality standards on the use of treated effluent and sludge from domestic sewage for agricultural purposes. The quality standards for treated effluent and sludge for irrigation have already been prepared by the committee. A standard for groundwater recharge is under preparation.

The Provisional Code of Practice for Treated Domestic Sewage Effluent used for Irrigation makes the following points:

1. The sewage treatment and disinfection plant must be kept and maintained continuously in satisfactory and effective operation so long as treated sewage effluents are, or are expected to be used for irrigation, or disposed according to the permit/s issued.

2. Skilled operators must be employed to attend the treatment and disinfection plant, following formal approval by the appropriate authority that the person/s is/are competent to perform the required duties necessary to ensure that conditions of (1) are satisfied.

3. The treatment and disinfection plant must be attended according to a schedule approved by the appropriate authority and records kept of all analyses and operations performed. A copy of these records must be kept at a convenient place for inspection at any time.

4. All outlets, taps and valves in the irrigation system shall be of a type that can be secured to prevent their use by unauthorised persons. All such outlets must be coloured red and clearly labelled so as to warn the public that the water is unsafe for drinking.

5. All efforts should be made to ensure that no cross-connections occur with any pipeline or works conveying potable water. All pipelines conveying sewage effluent must be satisfactorily marked with red tape, so as to be distinguished from domestic water supply. In unavoidable cases, where sewage/effluent and domestic water supply pipelines must be laid close to each other, the sewage or effluent pipes should be buried at least 0.5m below the domestic water pipes.

6. Irrigation methods allowed and conditions of application differ between various plantations as follows:

   Park lawns and ornamentals in amenity areas of unlimited access:
   - subsurface irrigation methods
   - drip irrigation
   - pop-up low angle (equal or less than 7°)
   - low pressure and high precipitation rate sprinklers (more than 20min/hr)

   Sprinkling should be practised at night and when people are not present.

   Park lawns and ornamentals in amenity areas of limited access, and industrial and fodder crops:
   - subsurface irrigation methods
   - drip irrigation
   - surface irrigation methods
   - minisprinklers
   - sprinkler irrigation is allowed if there is a buffer zone of 300 metres.

   For fodder crops, irrigation should stop at least one week before harvesting and no milking animals should be allowed to graze on pastures irrigated with sewage effluents. All cases of fodder irrigated with treated effluent should be reported to the veterinary services.

Vines:
- drip irrigation
- mini sprinklers (irrigation should stop before harvesting)

Portable irrigation networks are not allowed and no fruit is allowed to be collected from the ground.

Trees with fruits eaten raw without peeling:
- drip irrigation
- hose basin irrigation
- bubblers irrigation

No fruit is allowed to be collected from the ground

Trees with fruit eaten after peeling, nuts and similar produce:
- drip irrigation
- minisprinklers (irrigation should stop one week before harvesting)

No fruit is allowed to be collected from the ground. Nut collection is allowed.

Other irrigation methods may be allowed after formal approval by appropriate authority, which shall take into consideration the public health, agricultural and environmental aspects. Restricting measures could also be enforced for any irrigation method by the appropriate authority if with such measures health, environmental or others hazards are avoided.

7. The following tertiary treatment methods are acceptable:
   - coagulation plus flocculation followed by rapid filtration
   - slow sand filtration
   - any other method which shall secure the total removal of helminth ova and faecal coliforms down to acceptable level. It must be approved by the appropriate authority.

8. Appropriate disinfection methods should be applied when required by the irrigation standards. In the case of chlorination, the residual free and total level of chlorine in the effluent should be equal or more than 0.5 ppm and 2 ppm respectively at the point of use.

9. Suitable apparatus for the monitoring of all essential parameters as required by the appropriate authority should be kept on site at all times.

6.4 Reuse options

6.4.1 Irrigation

General comments

Efficient water resource management is realized by:

- Matching capacity to demand
- Integrating supply, storage, and disposal
- Establishing technological and cross-sectoral linkages of supply, treatment, and use.

In planning the use SBP STP of wastewater for irrigation, the following points should be considered:

1. Irrigation is practiced mainly in intensively farmed zones in dry climates. It is precisely under these conditions that a salinity problem is likely to occur either in the soil or in the water sources. The lack of sufficient rainfall and the scarcity of irrigation water may lead to inadequate leaching and to the accumulation of excess salts in the crop root zone unless special steps are taken to avoid it. There are methods of irrigation that can be used to control soil salinization.

2. When municipal water supply is drawn from the same sources as irrigation water, and its initial chemical quality may be already impaired.

3. The total soluble salt content of municipal effluent is always higher than that of the supply water, and thus the additional solutes must be added to the original concentration of the supply water. Literature reports a "pickup" of about 250ppm of soluble salts between supply water and effluent.

4. In Pafos the infiltration of seawater into the main sewer is expected to be 300m^3 per day. This will contribute circa 1000 ppm of salts into the final phase flow.

5. Excess irrigation water salinity may impair crop growth, and excess sodium may cause soil sealing to the extent of making it impossible to irrigate the soil. Table in Appendix VI. Gives the yield decrease expected by irrigation with water of increased salinity. Chemical amendments to the water or soil may be required to maintain its productivity.

Land application of treated sewage effluent is a simple and economically attractive method of treated wastewater disposal with potential agricultural benefits that can improve the overall efficiency of water utilization. The manner of application depends on the secondary objective of the operation, where the primary objective is the economic disposal of effluent in accordance with public health, environmental, and aesthetic considerations. If attainment of the primary objective is assured, there is a choice between simply getting rid of the wastewater and its constituents, or of utilizing it for the production of useful vegetation, be it agricultural, crops, plant cover for soil conservation, land reclamation, recreation, or landscape enhancement. If the principal secondary objective is disposal, then this is best accomplished by overland flow or rapid infiltration, both of which allow the application of large amounts of effluent to a relatively small land area in a short period of time. If plant production is the major secondary objective, then slow – rate application or simply irrigation is the proper method of applying the treated effluent. Although there may be some resemblance among certain technical details of the above methods, there are really large differences between them in their principle of operation. They also differ in their land requirements, economic performance, and criteria for pretreatment of the effluent prior to land application.

The overland flow and rapid infiltration treatment methods are based on achieving the fastest application rate possible consistent with soil properties, climatic conditions and the final standards of wastewater upgrading. The soil surface must be vegetated in the overland flow system (to avoid erosion) and occasionally harvested, but the installation is not operated for crop production. Application rates are site-specific and vary between 5 and 35 cm per week, or 3 to 15 m per year.

In contrast to the above disposal method, slow-rate application, or irrigation with wastewater, is based on the idea of utilizing both the water and the nutrients of wastewater to grow beneficial vegetation, usually agricultural crops. The application rate must therefore be adapted to crop needs, in the particular climatic conditions of the region of reuse.

Thus the most obvious and most important difference between wastewater irrigation and the rapid-rate disposal methods is that the application rate is approximately one-tenth that of the rapid-rate methods. The land area that can be irrigated is therefore roughly ten times larger for the slow-rate method than for the rapid-rate methods.

The positive and negative impacts are then summarized as follows in table 6.1 below.

Table 6.1
Positive and Negative impacts of reuse options

Disposal Method	Positive Impacts	Negative Impacts
Rapid infiltration	• Less land required • Less evaporation	• Need favourable recharge aquifer • No benefit from additional treatment from solar radiation
Slow rate application (irrigation)	• Beneficial effect on soil. • Control over distribution system	• More land needed • Dependence on farming activity in the region • Need for farmer training
Export from Region	• Opportunity for development in other regions • Maximization of benefits to national economy • Better integration into national water strategy	• Loss of direct benefits

Similarities and Differences between Effluent and "Normal" Irrigation Water

For our purposes, water from different sources should be compared on the basis of its physical, chemical, and biological properties in order to determine how these might affect the operation of an irrigation system, including possible effects on soil properties and crop response. The criteria applied to evaluation of irrigation water differ from those for domestic water supply. Potability for domestic supply is determined by medical and aesthetic considerations of the presence of pathogens, toxic solutes, colour, flavour, odour, and suspended solids. A useful exposition of these topics is elaborated in appendix VI.

Grop selection considerations and criteria

Grop selection should be based on three kinds of criteria:

1. Suitability of the crop to the general agronomic conditions of the site, considering climate, soils, markets, etc. In general, any of the crops grown by local farmers under irrigation would be considered suitable according to this criterion.

2. Constraints on crop production due to water quality changes, that is, salinity and toxic effects of specific ions.

3. Constraints on crop utilization or marketing imposed by public health considerations or regulations, considering both pathogens and toxic chemical compounds.

6.4.2 Irrigation of hotel gardens and public parks

The most practical way to return water to major users within the sewage collection area is to install a Treated Effluent Return Line (TERL) above the sewage collection main and appropriate trunk line. This is best done while trenches are open and all machinery and materials are on hand.

It should best be handled via the same contract as that for the sewage line.

Prior to a major decision however, the authorities (SBP, municipalities, WDD) should decide on the criteria for TE return to eligible users.

The situation in Pafos is fairly simple because:

- All major hotels are along the path of the main sewer line

- There is a natural slope towards the sea which favours the installation of one or two TE storage tanks which will then distribute the TE only to:
  - Football pitches and athletic stadia
  - Municipal Gardens and other public parks (parking lots, round abouts, highway dividing strips, fountains, etc)
  - Municipal watering tanker refilling stations
  - Church and school gardens
  - Plant nurseries within town boundaries

Hotels which have their own sewage treatment plants will need to decommission them when they are connected to the central sewage system. The cleaned out tanks may be used to store irrigation water returned to them via the TERL. To size the line and to make a comprehensive list of TE users within the study area a further purposely commissioned study will need to be executed and indeed quite early in the project.

The water, which is not absorbed by the TE approved users, will be available for the WDD to use in other re-use projects. It must be remembered that TE is not a resource to be squandered and wasted. The creation of large scale new uses must be discouraged while TE reuse must strive first in the minimization of potable water demand for non-potable uses.

The irrigation of hotel gardens and public parks and other green areas deserves serious consideration. This is especially so along establishments on the route of the central main along the coast

When the sewage collection system is completed each hotel as it is gradually connected, it will loose its internally generated TE supply. To maintain their gardens hotels will need to substitute this water using alternative supplies, most likely potable water. The most sensible solution will be to install a TE distribution system with outlet at each hotel and exploit the, by then, disused STP's of hotels as storage for irrigation water for their grounds.

There must be a specialized study for this in order to estimate the water to be returned to the coastal area and to size the pipe and pumping stations required to do this. This must be done well in advance of any construction work since the laying of this pipe must be done during the construction of the main coastal sewer. Surplus TE will be supplied to other users either local to the STP or through another system.

It must not escape the Authorities' attention that supplying TE to the local farmers at a preferential rate might be a compensating measure for the local residents.

Another nearby user might be the Pafos Airport which when upgraded it will need a lot of water for its landscaping (this however constitutes creation of a "new need").

6.4.3 Ground water recharge

Groundwater recharge is a practice used for water storage and for the control of seawater intrusion into over pumped aquifers. It is a practice, which is about to be implemented for the treated effluent of the Limassol / Amathus scheme and the WDD has plans for the other treatment systems. The practice of groundwater recharge has the advantage that it prevents water loss by evaporation while additional treatment of the effluent takes place in the aquifer. Pafos aquifers are amenable to this type of utilization as they are hydraulically connected. The precise way recharge may be effected is beyond the scope of this study.

The area where the Pafos STP will be constructed is a prime agricultural area and there is an irrigation system already in place. The system supplies annually circa 20 million cubic meters of water. By comparison the SBP system at its full development it will need to dispose of circa 7 million cubic meters of TE per year. The Pafos Irrigation Canal is a major feature of this scheme. The Canal is on open water course subject to all the advantages and disadvantages of such a system. The simplest reuse option is, therefore to feed the TE into the canal system either directly, after passage through a balancing tank and indirectly by recharging the aquifer feeding the canal. The major source for the Pafos irrigation Scheme is the Asprokremmos Dam. The water from this dam is considered unsuitable for (potable domestic) use and consequently the dam can be used for TE storage.

A specialised study should be undertaken to investigate the environmental and Public health hazards of implementing this suggestion.

7.0 ENVIRONMENTAL IMPACTS ON OTHER ISSUES

7.1 Standby generators

An STP and its associated PS are part of a system which must maintain high levels of reliability as the flow of sewage is virtually unstoppable once it starts. Electrical generators are installed in order to provide emergency power in case of power failure. While power failures in Cyprus are pretty rare it is prudent to provide for an emergency supply.

Such stand-by generators are started up regularly in order to check their performance and to keep the starter batteries charged. They are of course started when there is a power failure in which case they come-on automatically and they provide power through automatic change-over switches.

There are three possible negative environmental impacts from their installation and operation. These are:

- Exhaust gases
- Noise
- Leakage from fuel tanks

The first impact depends on their horsepower but it is no more than that of a large diesel engine of the types installed at other locations. The temporary nature of a stand-by generator's operation precludes any further meaningful discussion on the environmental impacts. It is assumed that the designers will select modern enginers fitted with the proper exhausts and silencers in order to minimize noise and smoke.

The question of stand-by generators at the pumping stations is a somewhat different issue. PS are in inhabited areas and the noise from generators can be less tolerated. This is especially so for PSKP which is located in a tourist area. One must of course presume that the power failure affecting the PS will be affecting the whole area and consequently most activity will cease and people will go to other areas of the city or modify their activities to suit the situation.

PSA and PSB can be fitted with stand-by generators without many problems. PSA is isolated and out of town while PSB can be adequately silenced and isolated. If a petrol engine is used instead of a diesel one noise and exhaust will not be more than those of a large saloon car.

PSKP need not have a special generator but one may be towed on site or one may be installed at a location separate from the PS. Both solutions will need to be of a low noise type and petrol engines are best suited for this purpose.

Fuel spillage can be mitigated by double containment and absorbent pads of the type typically used in fuel storage and transfer operations.

7.2 Emergency Overflows

Emergency overflows must be installed at the pumping stations and the STP. It will be difficult to imagine a sanitary system without an emergency overflow. The existence of these does not mean they will ever be used. They are there to provide a solution when no other means will be available. Such situation will be very rare indeed but one can imagine the situation after a major earthquake or an act of terrorism where the stand-by systems are also out of action.

The magnitude of the problem will depend on the volume of raw sewage that is released. The survival time of feacal coliforms in sea water is about 12 hrs. It is clear that these die off very fast and a restriction on bathing in the sea for a few days may be all that will be required to protect public health.

Overflows can be provided for PSKP and PSA whereas for PSB, an overflow is provided for into the storm drains. No other part of the system will be provided with an overflow. There is no need for an elaborate design or a special environmental study involving sea dispersion. If such a study needs to be made there is ample time to do it allowing for the collection of current data and marine biology information.

7.3 Storm water discharges

As a rule storm water discharges follow natural paths. During a storm, water will be precipitated in very large volumes during a small time period. There are statistical rainfall data from past years which can be used for the design of the storm water system. As an area is built up more hard surface is created and potentially larger volumes of water must be drained from urban than from rural areas of the same catchment size.

Rainwaters will wash down into the sea what they find in their path. Apart from natural debris such as dry leaves, tree branches, wood etc they will wash out into the sea dirt from roads, packing paper, plastic and anything that happens to be on the ground and in the storm sewers just before the down pour.

Natural passages must be preserved. In case of building development the same capacity of flow as that of the natural passage must be preserved. Where this has not been observed in the past serious incidents of flooding occurred.

Obstructions in the passage of water will also contribute to flooding conditions. So devise like filters, bar screens etc can be useful provided they are kept clean during a storm.

Rain water going to the sea will carry with it all the dirt on the roads therefore the negative impacts on the environment after a storm (which is a natural phenomenon and contributes to the natural balances in nature) will be concentrated on the floating debris that the stream will bring to the sea. This will appear on the cost and beaches a few days later, sometimes many kilometers away.

While dust and other heavy solids will sink, the floating material will need to be collected before, during or after the storm.

There are storm water control devices on the market which not only can they collect unwanted materials from reaching the sea but also can provide means for delaying the flow and thus reducing flooding conditions potential as well as the size of storm sewers. At the same time they can provide ways for collecting stormwater for future use during drier periods. All these are beyond the scope of this report but can be incorporated in a specialized study which can also locate positions of storm water storage systems thus adding to water availability in urban Pafos. At present they are considered a luxury and may be considered only in special areas and cases.

With regard to the natural passages included in the Pafos system the following apply.

Clear and construct a defined water path for all natural drainage passages which run through built up areas or areas destined to be developed soon. Such construction already exists for the Limnaria river between the Alexander the Great and Pafos Beach Hotels.

Another location is that by Venous Hotel by "Melania" Restaurant which will need to be cleared and cleaned. There is evidence of an active biotope there, also harbouring snakes, which may not be so desirable to preserve so close to a tourist area.

The other location (Katsikandaris) will need to be concreted and covered, possibly with removable concrete slabs.

7.4 Construction Phase Mitigation measures - general guidelines

The impacts from construction of the STP will be limited essentially to communities and areas on the main route for transportation of supplies. The types of impact will include:

- noise from construction plant
- noise and disruption from vehicles delivering supplies
- noise and disruption from vehicles used by staff and visitors
- dust
- waste disposal

As already indicated on previous reports on the same project during the start up phase of the new STP impact may arise from operation of the process under low load conditions. In this period, the volumetric and organic loadings will be substantially lower than design values. This arises particularly because of the absence of sufficient organic matter and other nutrients to develop and sustain the normal bacterial population in the secondary treatment process. Although this period should be brief pending completion of the sewerage network, it may be accompanied by a tendency to produce more than the expected level of odour, accompanied by a poor quality final effluent.

The sewerage construction phase will have more significant negative impacts, including the following in addition to those listed above:

- disruption of normal daily routes of people in the immediate vicinity
- increased possibility of accidents to the public (open pits, ditches, narrowed traffic, lanes, etc)
- excavation noise
- road traffic restrictions in streets undergoing works
- pedestrian traffic restrictions
- financial detriment to businesses, especially shops, to which access is temporarily restricted
- atmospheric pollution from construction machinery
- accidental disturbance to other underground services
- accidental destruction of archaeological sites
- odours
- impacts on flora and fauna.

The impacts from the construction of the STP will not, overall, be significant as this will be in an isolated location and ordinarily not many will notice the activity or will be disturbed by it. Noise at worst is a nuisance for one hundred or so meters and most construction dust will settle in less than this distance. The noise from the airport in considerably higher.

What will be more severe and more noticeable to the population will be the disruption of normal daily life where the collection system is constructed. Almost every street will be dug up and resurfaced. Experience from other towns recently and from the past experience of the SNB indicates that good planning can minimize the disruption. Experience suggests that fewer complaints will be generated by construction in residential areas than from that in commercial areas. This disruption is unavoidable and the best mitigation measures will be good planning, rapid work schedules including overtime and weekend work in some cases and good public relations involving the prior announcement of the works to local residents and strategic placement of warning signs.

The most significant positive impact will be the creation of jobs for very many people.

The many more issues that have been identified are either temporary as they pertain to the construction phase of can be classified as of lesser importance. Such as minor odour nuisance during pumping station and sewer servicing or exhaust gases from stand-by generators.

During the construction phase

- Provide good, detailed work plans
- Provide for accelerated work schedules in sensitive areas
- Provide for a public relations office to take care of justified complaints
- Make contract provisions to oblige contractors and subcontractors to respect:
  - working hours
  - archeological heritage
  - noise standards
  - safety practices

7.5 Control of Mosquitoes and other insects in water storage basins

Insect breeding in ponds is mostly associated with aquatic plants emergings from the water surface. *Culex* and *Anopheles* mosquito larvae are common in many regions and the presence of gnats is not uncommon in ponds with emerging aquatic plants.

Possible remedies include:

- The outlet of a pond should be a type that allows the operator to vary the water level. The water depth may then be decreased to a level which will expose to sunlight those parts of the plants to which larvae stick and so cause them to dry up and die. Varying the level of the water surface is a very effective prophylactic against larval development;

- Scum destruction also helps to control insects;

- Depending upon the availability of dissolved oxygen, larvivorous fish may be reared in the ponds. Suitable types of fish are *Gambusia, Lebistes, Tilapia* and Chinese grass carp.

- If a considerable infestation with flies occurs, pesticides spayed on to the inner slope of the embankments are effective as a means of insect control, but are not recommended for general application. Great care should be taken to avoid pesticides entering the liquid mass.

- Construct ponds with hard surfaces at the water level in order to prevent plant growth.

8.0 NEED FOR FURTHER STUDIES

A number of issues have emerged from the foregoing analysis, which lead to the consideration of their further elaboration through specific assignments with a clearer focus. It is up to the SBP and the other authorities with which it collaborates (Municipality, WDD etc) to decide whether the issues merit further in depth study. What follows are the consultants suggestions.

1. In close collaboration with the WDD the SBP should proceed to clarify how the TE will be reused. Once a strategic decision is taken at the appropriate level then the water should be apportioned to the parties responsible for its distribution and management.

   For example:

   - A certain percentage (or a certain quantity) will be returned to the hotels and to approved users in the SBP area
   - A certain percentage (or quantity) might be directed to the golf courses and the developments in the Ha-Potami area
   - A certain percentage (or quantity) might be reserved for farmers in the vicinity of the STP at Achelia and the Achelia Agricultural Experiment Station
   - The remainder will be made available to the WDD for transportation to areas beyond the SBP boundaries and for use as the WDD sees fit.

   Once this high-level policy decision is taken and it becomes clear who will be administering each reuse sub-option then the following studies will be useful.

   - A hydrogeological survey for the most suitable recharge point(s).
   - An inventory of the irrigation needs of hotels and public parks in order to decide on the size and route of the TE return system. This will involve the location of strategic storage / gravity supply tanks and the necessary pumping stations. This must be done very early on at the design stage to allow concurrent construction with the sewage collection system.

2. The most hazardous material at a STP of the magnitude proposed for Pafos is Chlorine. Dispersion modeling of an accidental Chlorine release will be a preliminary first step towards a full risk assessment and an eventual elaboration of a contingency plan against the chlorine hazard. The proximity of the Airport and the Military Air Base make this an important issue as a large scale accident or even a terrorist action might create a very serious situation for which the authorities will need to be prepared.

3. The SBP must proceed as soon as possible with the registration of all possible industrial sources and the characterization of their effluents. This may call for a separate specialized survey.

4. One possibility worthy of investigation by SBP (with or without the collaboration of other Sewerage Boards) is that of solar drying. The solar drying that the consultants envisage will be done in specially constructed solar dryers where warm air will by supplied to the sludge bed, which will be continuously turned. To enhance drying, the mechanically dewatered sludge might be mixed with shredded waste paper and other such waste material. The final product will be taken to incineration or spread on land.

5. The area where the Pafos STP will be constructed is a prime agricultural area and there is an irrigation system already in place. The system supplies annually circa 20 million cubic meters of water. By comparison the SBP system at its full development it will need to dispose of circa 7 million cubic meters of TE per year. The Pafos Irrigation Canal is a major feature of this scheme. The Canal is on open water course subject to all the advantages and disadvantages of such a system. The simplest reuse option is, therefore to feed the TE into the canal system either directly, after passage through a balancing tank and indirectly by recharging the aquifer feeding the canal. The major source for the Pafos irrigation Scheme is the Asprokremmos Dam. The water from this dam is considered unsuitable for (potable domestic) use and consequently the dam can be used for TE storage. A specialised study should be undertaken to investigate the environmental and Public health hazards of implementing this specific suggestion.

6. Sludge management will potentially be the most serious problem. There are many proposals and literature references but these are largely academic as none has been practiced on a large scale in Cyprus. The SBP perhaps in collaboration with the other SB must undertake a serious, practical approach the sludge problem. Reliance on consultant's studies is not enough. There can be an endless series of studies but unless a practical step towards implementation under Cyprus reality is undertaken, a solution to the sludge disposal problems will not be found. Pilot trials and feasibility studies will be needed quite early on in order to make the most cost effective decisions.

Once it starts the flow of sludge will be unstoppable and there must be a practical and both socially as well as environmentally an acceptable solution if the sewage sludge problem reflects negatively on an otherwise most desirable infrastructural project. There is no shortage of technical solution proposals and even more are expected to emerge as the full implications, to the water treatment industry, of the EU directive on landfills is realized.

There must be Cypriot experience on which to base the final decisions as the solution or combination of solutions will reflect on the operational economics of the entire scheme. The cost of sludge disposal must be included in the SBP fees.

7. Although a luxury at present a storm water storage system might not be a bad idea in view of the water shortage problems which will be recurring more frequently in the future. There are systems which can provide ways for collecting stormwater for future use during drier periods. All these were beyond the scope of this report but can be incorporated in a specialized study which can also locate positions of storm water storage systems thus adding to water availability in urban Pafos.

9.0 GENERAL DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

9.1 General Discussion

Sewage collection and treatment systems have been developed, installed and refined in order to improve the quality of life.

Large urban systems have been and are being installed in Cyprus through the various local Sewerage Boards. Some smaller rural systems have been installed and more are being planned. Small local systems serving neighbourhoods and refugee estates are in operation while there are scores of systems installed by private industry and hotels.

There can be no doubt as to their overall possitive environmental impact not only because of their inherent nature to protect health but also through the provision of water suitable for reuse.

The negative impacts, which in effect are non-existent in well designed and operated systems which are part of an overall water management strategy, are in fact the accumulation of bad experiences from past mistakes or omissions. These are indeed very few in number.

It is therefore difficult to find negative impacts in a case like Cyprus and particularly Pafos where the high standards of living, the intense tourist industry development, the density of population and the need for additional water, dictate that the sewage system is installed without delay.

With the proper design of mitigation measures and the expenditure of the analogous funds there is no reason why there would be any form of nuisance or danger to public health.

Decisions on the type and location of effluent discharge and the level of treatment are crucial and should not be made without adequate information. Wastewater volume and strength are basic information for the planning process, and realistic estimates and projections of volume and pollution are important to establish the magnitude and timing of the need for collection and treatment. In making and updating projections, other planned development activities should be taken into account so that extensions or expansions of wastewater infrastructure can be coordinated with them.

The level of treatment and the magnitude of pollutant removal a treatment process must achieve depends on the performance standards which apply to the system These are usually expressed as limitations on the concentrations of regulated substances permitted in the treated effluent. In the case of effluents which are to be applied to crops or otherwise used on land, the standards are set to prevent crop and groundwater contamination as well as to protect public health. National standards for effluent reuse already exist in Cyprus.

As already stated above, from a macro point of view, the entire scheme can only have positive environmental benefits provided that:

- The collection system minimizes energy consumption
- The treatment system
  - Minimizes energy consumption
  - Contains odours
  - Is designed to be "friendly" to its neighbours
- The "product" reuse system:
  - Maximizes resource recovery (water, energy, sludge)
  - Becomes part of an integrated strategy which maximizes benefits to the National Economy

Therefore the discussion on mitigation measures can only be a general one provided the commitment has already been taken to install an intensive treatment system which causes the minimum of disturbance to the public.

9.2 Conclusions

1. It is restated here that unless they are not correctly planned, designed, constructed, operated and maintained, wastewater projects are likely to have a negative impact overall, failing to yield the full benefits for which the investment was made and adversely affecting other aspects of the environment besides. However, there are several characteristics common to many of the potential impacts and mitigating measures which should be emphasized as special issues throughout project preparation, assessment and implementation.

   These are:
   - the importance of sound and comprehensive wastewater system planning;
   - the fundamental dependence of wastewater projects on proper operation and maintenance (and thus on strong institutional support for both);
   - selection of the appropriate technology;
   - the necessity for an effective industrial wastewater pretreatment program in any municipal system serving industrial customers;
   - the need to consider a number of potential sociocultural impacts which are sometimes ignored in project preparation

2. Provided that sludge is used as per the provisions of the EU Directive there can only be positive impacts from the re-use of wastewater. Land use will be affected in the areas where the treated water is directed. These areas will appreciate in their value as arable agricultural land. The positive impacts of this can be felt as far as Peyia because the WDD have expressed some interesting ideas as to how the treated effluent can reach there through some expenditure of funds for a pipeline to connect the STP at Achelia with exesting infrastructure.

3. Infiltration has been allowed for in the pipelines from point C to PSA. This allowance amounts to 163,8 m^3/day. Assuming that 30% of this (50m^3/day) will be seawater (3,5% salt content) and using the average flows for phase I (5400 m^3/day) and phase II (10,800 m^3/day) it is anticipated that phase I treated effluent will be burdened with an additional 320 ppm of salts and phase II with 160 ppm.

   Considering that the final treated effluent will be mixed with other irrigation water then the final effect to the water users will not be noticeable.

4. With regard to the major public concern of odour, this study concludes that provided the measures discussed in this report are taken there will be no odour nuisance in the vicinity of either the STP or the pumping stations. The results of the dispersion modeling show that after employing the mitigation measures (covering, deodorization) no foul odour will reach more than 35-40 metres.

5. In relation to the prevailing winds the STP is in a favourable position minimizing the probability of odour movement towards the village.

6. Even for PSA where the model was run the isopleth lines showed very low values only up to a few meters from the outlet. The particular pumping station is on the coast where there is even a slight breeze most of the time. This aids dispersion further. With odour control devices in place none of the pumping stations will be a source of odour.

7. With regard to the operation of the STP its isolated location is in itself a noise mitigation measure. However noise levels of the order of 65-70, dBA may be expected near equipment such as rotors, compressors and motors. Noise is a particular nuisance at night when background noise levels are low.

Noise at pumping stations is a rather more serious issue as these will be mostly in residential areas. Experience shows that with carefull design normal PS operation does not produce any noticeable noise beyond the perimeter.

9.3 Recommendations

The design and operation of a modern STP in Pafos of the type already operating in Cyprus already minimizes the potential hazards to personnel, neighbours and users of the wastewater.

Proper training and instruction as well as monitoring are adequate measures to prevent unmanageable situations. The construction and operation of hundreds of large and small (in hotels) STP's throughout Cyprus has given good records in the past.

The fundamentals of occupational health and safety should include operations and maintenance training on the actual equipment. Any personnel who may have to enter confined spaces, work in deep trenches, maintain electrical equipment, or handle chlorine, biogas or other dangerous chemicals must be properly equipped and drilled in safety and accident response procedures. "Training the trainers" is a good concept, so that system staff can continue training programs throughout the life of the facilities.

The siting of wastewater treatment plants is more often than not accompanied by serious public objections essentially because of two reasons:
1. The fear of odours, and
2. The perceived loss in the value of land

With regard to the first and in relation to the present case it has already been decided that the most potentially odourous part of the plant (headworks and pre-treatment) will be covered and fitted with odour control devices. In addition odour control measures through out the plant will be taken in any case. It is neither to the interest of the SBP nor the Government to avoid the installation of odour control measures.

The proximity of the Air Force Base and the International Airport are two additional stakeholders in the area who will also demand very high air quality levels.

The large distance (1800m) from the boundary of the Achelia building zone to the boundary of the treatment plant will act as an adequate measure of protection against odour in case of minor malfunctions.

With regard to the second issue, that of the perceived loss of land values, there can be a number of possible compensating measures to be discussed. These may be offered as a "phychological" counter measure and to balance the widespread public feeling of "injustice" in the community of Achelia. The measures, especially acceptance of the zoning proposed by the Achelia community, will increase the credibility in the studies performed and the Authorities decisions.

Such measures may be:

- Extension of town planning zones (residential) to cover all the private land in Achelia. This last measure will have no cost to the Government but will give the inhabitants of Achelia the opportunity for financial benefits. This rezoning will be a practical demonstration of the fact that there will not be an odour problem any way.

- Preferential allocation and favourable pricing of irrigation water

- A lump sum compensation to the community
  - Once
  - Yearly

A start-up plan should be prepared for any new wastewater facility of significant size to ensure that the requirements are met. The plan should provide for assembling staff, maintenance equipment and spare parts in advance of need, training all personnel, and establishing revenue sources and budget.

Because this is an environmental project, good construction inspection practices to ensure that the system is built to specifications is also good environmental management practice. Particular attention should be given to adherence to the mitigation plan provisions to protect the sea, and lands.

An operational monitoring program should be developed to:
- observe trends in influent volume and strength
- detect hazardous substances entering treatment works
- enforce industrial pretreatment regulations
- control the treatment process
- assess and manage treatment plant performance
- monitor environmental quality at disposal locations
- ensure sludge products and reclaimed wastewater meet reuse standards.

In designing the monitoring program, the emphasis should be on supporting sound operations of the wastewater system. This entails establishment of system performance standards. Data should be collected to monitor attainment of those standards, interpreted and then delivered efficiently and timely to those who must make operational decisions. Monitoring data is also useful to designers for improvement of future projects. All too frequently, monitoring programs are seen only, or primarily, as enforcement tools. Although enforcement action may be necessary to achieve compliance with standards in some cases, a timely report placed in the hands of a conscientious treatment plant superintendent may be more effective in protecting the environment.

The most hazardous material at on STP of the magnitude proposed, is Chlorine. The transportation, storage and handling of this toxic gas must follow the appropriate procedures and the WDD has adequate experience of this. Adequate security and proper custody of this material is of paramount importance as it could be the target of terrorist or enemy activity. The Civil Defence authorities must elaborate a contingency plan.

It is recommended that all potentially problematic plant areas be covered and vented through the appropriate odour control devices. These are extensively discussed in the appendices.

It is recommended that the external appearance of all STP buildings be architecturally designed as to give the impression of a farmhouse or a vacation home.

Summary of Mitigating Measures

Pumping stations

- Architectural design to blend with the rest of the structures in the area. Consider "disguise" if necessary.
- Fit appropriate odour filters and maintain slight negative air presure inside the building or enclosure.
- Use antivibration mountings, vabration isolation joints and silencers as appropriate.
- Design and adhere to a thorough maintenance program

Sewage Treatment Plant

- Enclose headworks
- Vent preaeration exhaust through a properly designed odour control system.
- Enclose sludge and solids handling operations. Maintain slight negative air pressure and vent through odour control devices.
- Minimize the creation of water sprays and mists.
- Create a site boundary with trees.
- Provide for future implementation of enriched air supplementation of the intensive oxidation processes.
- Make provisions for perimeter H_2S and NH_3 monitoring
- Design and adhere to a thorough maintenance program

During the construction phase

- Provide good, detailed work plans
- Provide for accelerated work schedules in sensitive areas
- Provide for a public relations office to take care of justified complaints
- Make contract provisions to oblige contractors and subcontractors to respect:
  - working hours
  - archeological heritage
  - noise standards
  - safety practices