STUDY
of
SIDON REFINERY
WASTES AND WATER PROBLEMS

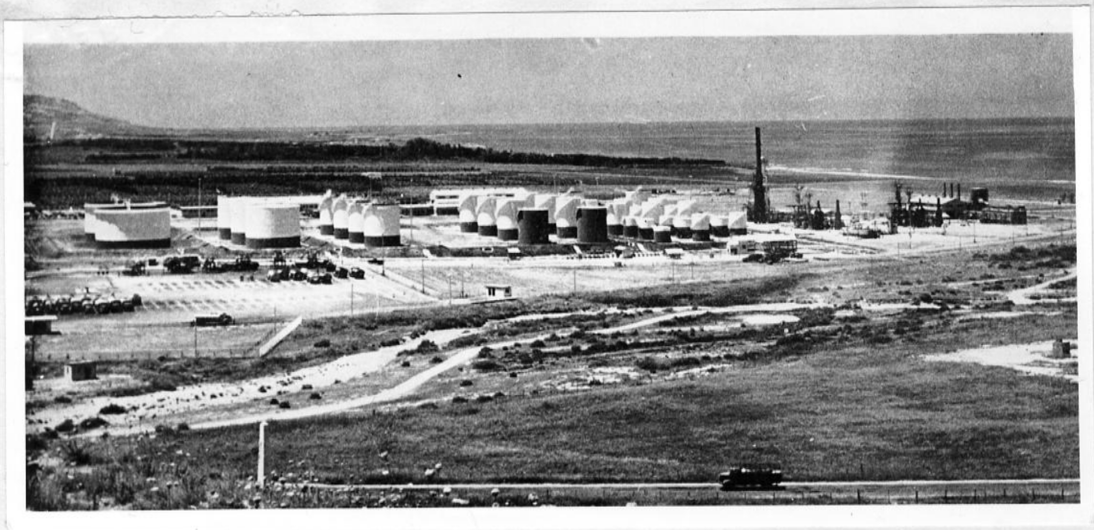
By

ZOHRAB I. MARDIROSSIAN.

A Thesis submitted to the School of Engineering, American University of Beirut, in partial fulfillment of requirements for the degree of Master of Engineering with major in Sanitary Engineering.

Beirut
October 1965.

Advisors:
Prof. E.S. Hope.
Prof. A.N. Acra.



The Mediterranean Refining Company Installation at Sidon, Lebanon.

An investigation of the existing local conditions regarding industrial wastes, water usage in industries, and the pollutional aspect of the coastal waters, has been recently attracting the attention of the Lebanese authorities.

For the purpose of this study the petroleum industry was selected with the intention of investigating the water and wastes problems in the two refineries existing in Lebanon. Unfortunately, the Tripoli Refinery management refrained from cooperating. Their letter of February 22, 1965 includes the following statement:

> "We regret that we are not able to offer any special facilities beyond those which are normally extended to student visitors."

On the other hand, the Sidon Refinery management's receptive attitude prompted the limitations of this study to the latter refinery. In their letter of March 18, 1965, the only condition stipulates:

> "It is understood that no obligation of compensation whatsoever will be due to you by Medrico for the study you intend to undertake."

In Sidon Refinery; based on the findings of the survey completed during the period March 3, 1965 to August 31, 1965, feasible solutions to all problems encountered or anticipated are proposed and reported herein.

This report describes the survey made, the data collected, the conclusions drawn, and the recommendations made with respect to the refinery water supply and wastes collection and disposal system.

The major phase of the survey includes the plant study, measurement of wastes and water flows, sampling and analysis of water and waste waters, and the report of findings. The report also includes recommendations, particularly with respect to reclamation of process waste water that will do much towards solving the problem of providing an adequate quantity of water of a quality suitable for re-use.

Emphasis has been placed on the problem of water pollution caused by discharges of refinery wastes to the sea. The preliminary survey seemed to encourage the proposal of an extension of the existing outfall sewer further offshore into the sea. However, the data collected eventually indicated that such an extension is not warranted. The possibility of not discharging the wastes to the sea was entertained as an alternative thus favoring reclamation of the wastes in response to the present water conservation concepts.

Acknowledgement

In preparing this report free use has been made of unpublished materials and maps in possession of the refinery for which individual credit cannot be given. However, the writer is indebted to all Sidon Refinery personnel who gave all possible information and assistance which led to the success of this study.

The writer also expresses his gratitude to his advisors Professor E.S. Hope, School of Engineering, A.U.B., and Professor A. Acra, School of Public Health, A.U.B., for their generous assistance in reviewing the entire work in an early draft, and for their valuable suggestions and advice to cover this particular field.

Special appreciation is expressed to Professors S. El-Khouri and C. Inglesis, School of Engineering, A.U.B., for their help and cooperation in the completion of this work.

The writer is also grateful to the Associated Consulting Engineers, Beirut, for their cooperation in furnishing some useful information for the project.

Finally, to all those people, named and unnamed, and to those who have encouraged me in this study: my very sincere thanks.

Z. I. Mardirossian.

Beirut,
September, 1965.

Chapter (Cont'd).

1 -- INTRODUCTION

Pollution of natural waters by refinery wastes is objectionable and damaging for various reasons. In an effort to abate such pollution, and for the sake of preservation of natural water resources, the possibility of water reuse at the Sidon Refinery appeared to be warranted.

1.1 Refinery Wastes

Prior to World War I, the problems of water pollution by refinery wastes were insignificant throughout the world. This was mainly because refineries were located in the oil-producing and scarcely populated parts of the world, and were relatively small and uncomplicated.

Since then the pattern has changed radically. Refineries are larger and more complicated and, furthermore, they are to an increasing degree being built in the consuming and populated areas. As a consequence, the problem of wastes treatment and disposal in any modern refinery became more complex and began to receive much attention. Suitable methods and equipment are provided and used nowadays by refineries for handling, treating, and disposing the wastes, so as to prevent any significant detrimental effect on the receiving waters that would impair its beneficial uses.

While every refinery is confronted with the problem of recovering oil from waste waters, may other controls must be maintained to insure that no effluent creates objectionable conditions on the receiving waters. The great variation in control methods in refineries depend on such factors as: (a) nature of crude oil, (b) processing methods, (c) products manufactured, and (d) nature of waters into which refinery effluent is discharged. The important thing to a refinery and pollution control official is the condition of the receiving waters. Waste treatment facilities must be designed to control the contaminants' level and avoid pollution of the receiving waters.

In Lebanon, two refineries are established: one by Iraq Petroleum Company in Tripoli, and the other by Mediterranean Refining Company in Sidon. Both are situated on the sea shore where advantage is taken of the possibility of discharging their effluents to the sea as an ultimate method of disposal. These effluents are objectionable and quite capable of causing excessive sea water pollution unless properly pretreated. As for sea water pollution it is necessary to guarantee the production of an effluent that meets in every way the state and company pollution control objectives, which may be summarized in general terms as follows:

a) To prevent the existence of public health hazards, nuisance and esthetically objectionable conditions.

b) To protect the beneficial uses of receiving waters, and

c) To cause no harmful effects on wildlife and fish.

Antipollution legislation and regulatory action do not provide the sole approach toward meeting these objectives, but technical knowledge and the refinery's attitude of cooperation are equally important for the abatement of natural water pollution by the refinery wastes.

1.2. Water Use in Refinery

Water is an essential and valuable substance in all processes of petroleum refinery. The controlling factors in determining its value are need, accessibility, quantity, quality, and the ability to pay for it.

A petroleum refinery requires a large volume of water in every phase of its operations. This great water requirement has made refineries extremely water conscious, especially in areas where the quantity of water is limited, or in other areas where the quality is not satisfactory. In an effort to overcome the problem, intensive and cooperative efforts by refineries to seek measures whereby water might better be conserved have been directed towards water reclamation and re-use.

In the Sidon Refinery, which is self-supplied with well water of good quality and sufficient quantity, no problem of deterioration or shortage of fresh water is facing the refinery at present, However, the question arises when does water shortage exist? Or, what may happen 5, 10, or 20 years from now? No one can answer with certainity such questions, but one reasonable prediction is that reuse of water will become the rule, not the exception, and many times of reuse of the same water must be anticipated.

1.3. Purpose and Scope

The prime objective of this work is to conduct a complete survey and investigation of the existing water and waste facilities on which to base recommendations to justify their adequatness and proper functioning. A further objective is to study the practices and proceduces used in the refinery water supply and waste treatment facilities, in order to make recommendations to modify or introduce changes on either system, if necessary.

In organizing the items considered in this study, priority was given to:

a) Identification of sources of water and waste waters.

b) Measurement of quantities of water and waste water.

c) Examination of water and waste water, and

d) Definition of the conditions under which any change in the system is warranted.

All laboratory tests were carried out in the School of Public Health, American University of Beirut, except when otherwise stated. Standard Methods of the Examination of Water, and Waste Water[1] was used as the main reference for all analyses.

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(1) "Standard Methods of the Examination of Water, and Waste Water", A.P.H.A., 11th edition, New York, 1960.

Conservation of water did receive much study due to the decreasing availability of good water supplies in the area, and the increasing demand for more water by the refinery. Conservation is achieved through water reclamation from process waste water that is now discharged to the sea in large quantities.

Starting with the actual situation in the refinery and based on the information provided by the evaluation of all data collected, each possible improvement and recommendation is so planned that it can be developed later to keep pace with the changes occuring in the refinery in the predictable future.

2.1. General Description

In 1952, Lebanon was importing part of its kerosine, gasoline, and diesel oil from the neighboring Arab countries. With crude oil flowing across its soil, the Lebanese Government sought self-sufficiency for its people in refined petroleum products. To bring this about the Mediterranean Refining Company, Medreco, as it is dubbed, was formed and selected Bechtel as designer and builder of the new Sidon Refinery.

Work on the refinery began in January 1952 and was completed in August 1955. With the refinery placed in operation Lebanon became independent of outside sources for its heavy requirements of refined petroleum products, including high-octane gasoline.

The area of the refinery is about seventy seven acres, located approximately six miles south of the ancient city of Sidon, and about 300 feet from the tanker-loading terminal of the Trans-Arabian Pipeline (Tapline). Figure 2.1. shows the location of the refinery and vicinity.

The refinery, like any modern oil refinery, is a complicated assemblage of furnaces, heat-exchangers, control-panels, and miles of pipes, pipe fittings, and valves in intricate combinations. It is beyond the scope of this report to discuss or describe in detail all of the operations of the refinery units, but a very brief description of the special operations pertinent to this survey may be of interest.

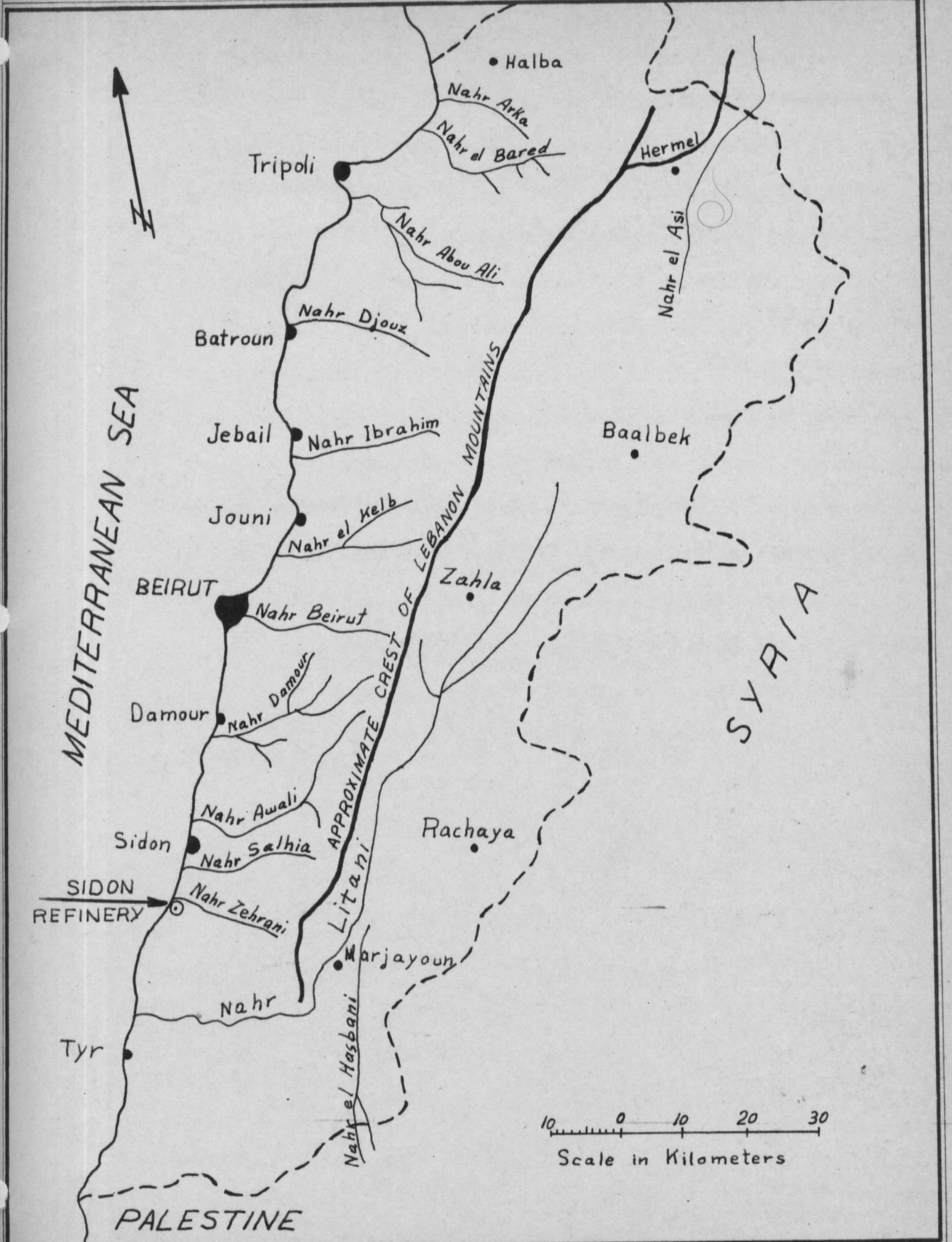

Figure 2.1. Location map of Sidon refinery

The crude oil, as it comes from Tapline, picks up heat, at first in the fuel oil heat exchangers, and then enters the tubes of a separate furnace called the "oil heater" where oil burners raise its temperature to above 700°F. This hot oil then enters the distillation tower at a point some distance from the bottom, accompanied by superheated steam. In this tower, fractionation takes place. Gasoline vapors are taken off overhead; next a kerosine cut; then diesel oil; and finally the residual oil forms the fuel oil cut at the bottom of the still. Each fraction is then sent in a never ending stream to other units of the plant for processing and up-grading into finished, saleable products. The up-grading is accomplished by the addition of foreign substances in a definite manner, or by rearranging the molecular structure of the existing molecule. Some of these processes are termed as:

a) Stabilization. - A process in which the low volatile components under pressure in a high efficiency column are separated and distilled off fractionates.

b) Alkali Treatment.- A process used extensively for the treatment of distillates for the removal of hydrogen sulphide.

c) Catalytic Reforming.- A process whereby naphtha and other light straight-run distillates are reformed in the presence of hydrogen which serves to "saturate" any olefines and convert them to paraffins.

d) Sweetening.- A treatment which renders a sour product sweet by chemical action.

e) Blending.- An intimate mixing of the various components in the preparation of a product to meet a given specification.

The petroleum products are then delivered for storage and distribution.

From the various processes streams of waste water are released and collected for proper treatment and disposal.

The Sidon refinery is a small one with limited facilities for the manufacture of various types of products. Since 1955, it has undergone a continuous expansion which can be readily observed from Table 2.1. At present, with the latest addition of a new distillation unit, the refinery's nominal crude oil input capacity increased to 16,500 barrels per day. Plans for further expansion, based on meeting the increasing need resulting from the growth and development in Lebanon, are expected to arise in the very near future.

2.2. Existing Waste Treatment Facilities

The refinery has a good waste water system which segregates all waste streams according to quality and pollutional content. There are three main segregations: domestic sewage, storm water, and process waste water.

Sewage is segregated from process waste water and then discharged into septic tanks. Process waste waters from the process and storage areas drain through a separate system and are treated for oil removal. Storm waters are segregated and treated in two ways depending on the expected oil contamination. All effluent waste streams are then collected and disposed to the sea through an outfall extending about 100 feet offshore and discharging at the bottom 6 feet below water surface.

Table 2.1. Yearly Crude Oil Input and Manufactured Products+

	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964
INPUT :- thousand barrels										
Crude Oil	2754	3613	4093	3546	4132	4595	4760	4779	5172	5400
PRODUCTS:- thousand barrels										
Liquified Petroleum Gas	—	—	—	12	56	81	104	203	98	99
Gasoline	487	658	765	625	730	802	765	788	882	1017
Kerosene	253	316	378	307	348	472	434	604	703	594
Diesel Oil	660	907	1081	834	1014	1032	1245	963	924	919
Fuel Oil	1211	1575	1701	1622	1817	2049	2031	2238	2381	2537
Total:	2611	3456	3925	3400	3965	4436	4579	4596	4988	5166
LOSSES :- thousand barrels										
All Sources	143	175	168	146	167	159	181	183	184	234

\+ Table compiled from records supplied by courtesy of Mediterranean Refining Company, Sidom Re finery.

The present waste collection and treatment systems are shown in Figure 2.2.

2.2.1. Domestic Sewerage System

The sanitary sewerage system is designed to flow under gravity. It collects raw sanitary sewage from offices and workshop facilities and conveys it to two septic tanks. The effluent from the septic tanks passes to the outfall sewer which conveys the discharge to the sea. About halfway between the septic tanks and the point of discharge to the sea, the system is joined by the effluent line from the oil-recovery plant.

A general layout of the system, with details of pipe sizes, slopes and olevation is shown in Drawing No. 1 (Appendix).

2.2.2. Process Waste Water System

The combined process waste water can be divided into three classes: clean water, oily water, and process water. The clean water includes cooling water, boiler blowdown, and storm water. The oily water includes pump leakage, tank drainage, sampling taps spillage, line leakage, loose connection leakage, equipment washings, and others. The process waste water include all concentrated process waters.

In the refinery cooling water is segregated and recirculated, whereas both the oily water and the process water are treated and discharged to the sea.

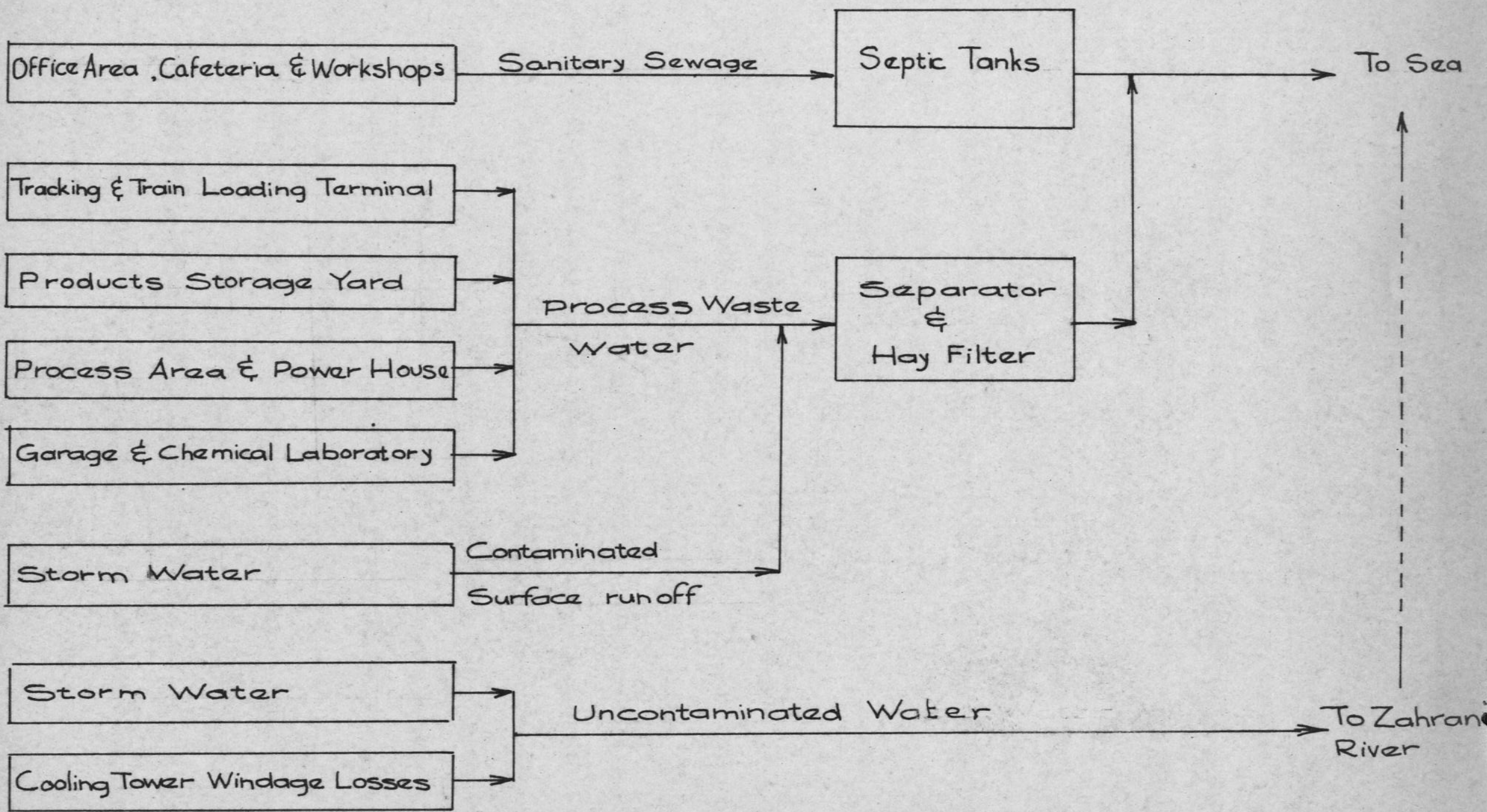

Figure 2.2. Present waste water collection and treatment system

Process waste water derived from all the above mentioned sources collect in a network of underground sewer system, laid out with sufficient hydraulic head available to drain and pass the waste water through the oil recovery treatment plant. The quantity collected by the system represents more than 90% of the process waste water in the whole area, while the other small oil free waste streams are by-passed the treatment plant and discharged directly to Zehrani River.

The principal processes used for the treatment of process waste water are gravity separation followed by filtration through a hay medium. The essential features of the system are: two separators in series, a detention pond, a sludge basin, and a filter unit. Drawing No. 2 (Appendix) shows the flow diagram of the present oil recovery system with the essential details involved.

The process waste water in the sewer is run initially to a distribution box equipped with a coarse screen to prevent large floating objects from entering the treatment unit. A maximum flow of 400 gallons per minute is allowed to the primary oil-water gravity separator, while greater flow is directed to the detention pond with a holding capacity of 600 gallons per minute for 4 hours. The detention pond is utilized to reduce the peak rate of flow to the oil separator. Impoundment or storage in the detention pond commences when the rate of flow to the distribution box exceeds 400 gallons per minute, and the liquid drains back by gravity when the rate of flow drops below 400 gallons per minute.

The waste water leaving the distribution box enters the primary separator through an orifice which regulates the flow to maximum of 400 gallons per minute. It then splits and passes through an inlet into the separator which is divided into two channels, each being 4 feet deep, 5 feet wide, and 20 feet long. The waste water finally passes under a curtain wall to the outlet of the separator. In this process, oil rises to the surface, sediment settles to the bottom, and relatively small concentrations of oil and suspended solids pass through the separator. All the oil floating on the surface is skimmed off, collected in an oil sump, then pumped to the slop tanks and returned to the refinery for processing. The efficiency of recovery is not very high. In 1964 the slop oil recovered by the separators averaged 16 gallon per day.(2) The sludge accumulated on the bottom is removed periodically and pumped to the sludge basin to settle so that more oil can be recovered while the residue is pumped and dumped into pits about 200 feet from the sea shore.

The waste water after leaving the primary oil separator, flows by gravity into a larger rectangular secondary oil separator where the waste water is allowed to stand still long enough so that the runaway oil floats to the top and the heavy materials settle to the bottom. Again, a stolled pipe skimmer skims the floating oil off-the top and collects it in a sump. The oil is then pumped to the slop tanks, whereas the sludge accumulated on the bottom is removed periodically and pumped to the sludge basin for further oil recovery.

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(2) Medreco-Sidon Refinery, Process Engineer; Personal Communication.

Waste water from the secondary oil separator is sent to the filter unit of hay medium which is assumed to perform two functions-filtration and absorption. Suspended solids are cought or filtered in the interstices of the medium; oil is absorbed by the filter medium as it passes through. Once the medium becomes saturated, it is removed, and the frequency of removal depends on local conditions and experience of the operator. Disposal of the spent filter medium is accomplished by incineration in a single stationery - hearth incinerator.

The effluent from the filter unit joins the domestic effluent line, and the combined effluent is discharged into the sea through an outfall.

2.2.3. Storm Water and Drainage System

The topography of the refinery land is moderately sloping down westward toward the sea, thus providing good natural drainage. The bulk of the refinery is drained by a system of shallow ditches or channels capable of handling even peak surface runoff.

The refinery surface runoff could be divided into two major parts: one covering the process plant and the tank farm yard, and the other covering the office area and the outlying areas not yet developed. Within each area, surface runoff is segregated into two categories on the basis of expected contamination with oil.

Contaminated storm water from processing and tankage areas is partly drained to the sewer system and partly collected in a series of ditches. All are coveyed then to the separators for treatment. Uncontaminated storm waters from both areas are collected and run directly to the Zehrani River near the Refinery.

The combined system of sewers, channels, and ditches is capable of receiving storm runoff at whatever rate it may be running from the drainage area.

2.3. Water Supply System

The present water sources of the refinery are three private deep drilled wells which are said to range from 600 to 700 feet in depth. The wells are 6 inches in diameter and their combined yield is said to be 4600 gallons a second.

The wells are under artesian conditions but water hardly comes out to the surface under any significant pressure. Hence, a motor-driven vertical centrifugal pump is installed on each well to raise the water and force it directly into a combined main or header with laterals distributed in various parts of the refinery. The pumps, with two electric and one diesel source of power for pumping, are not operating on a predetermined schedule, but are controlled automatically. The automatic operation of the pumps is controlled by the consumption variation or fluctuation of pressure in the water. In other words, they operate only when the pressure in the main drops to a minimum permissable of 40 psi. Usually, the system has two pumps operating 24 hours a day, and a third standby pump is available to draw water when needed.

The refinery does not meter its water flow for accountability, or other reasons. However, estimates of present water supplies based on estimates by technical personnel in the refinery, amounted to 5,000 gallons a minute - or about 400 gallons for each barrel of crude oil processed.

The water supply is used as a; (a) coolant for the transfer of heat, (b) prime mover for steam power, (c) solvent for performing chemical operation, (d) process agent for its effect on vaporization and system vapor pressure, and (e) source for drinking and domestic uses. It is used also for fire fighting, gardening and washing purposes.

A substantial volume of water supply has been saved by the re-circulation of cooling water, where the water is used repeatedly in an open-recirculating cooling system. The cooling device includes water cooling tower in which cooling air is sucked out at the top of the tower by means of fans operating 24 hours a day. Further saving of cooling water was made possible by the use of an air-cooling system that is newly installed with the new crude unit in the process area.

Aside from the cooling water, the refinery demand on ground water resources is still so great that a thought study on the possibility of developing a more economical solution to make significiant reduction in water intake appears to be necessary to meet possible future shortages of fresh water.

This chapter presents the established information and findings of the survey pertaining to the refinery water usage and waste flows. Flow records and laboratory data are tabulated and presented herein as a basis for all anticipated design works.

3.1. Domestic Sewerage System

3.1.1 Sewage Flow

The average daily flow of sewage depends on the average water consumption for domestic purposes. Hence, in determining its value, it is pertinent to obtain data on the number of employees and water consumption in the area contributing domestic sewage.

As previously pointed out, the water supply system shows no actual records on quantity of water used for domestic purposes. Therefore, an estimate of sewage flow rates based on domestic water consumption proved to be difficult. Besides, the actual field measurement of sewage flow rates in the system proved to be difficult too, because the sewers are deep and the pipe slopes or quantity are so small that they could not provide the necessary drop for installation of measuring devices, such as flumes or weirs. In such circumstances, volume-measurement methods capable of great accuracy is recommended for measuring the sewage flow in the system. The salt dilution method may be adopted for measuring the flow as long as the chloride ion concentration in the sewage is low or is constant. However, for small flows of sewage in the system the volume-measurement method is more satisfactory and far simpler.

With reasonable care in measurement, using a stop watch and a bucket, the sewage flow over a period of 8- hours was measured from which maximum flow rates observed. The average quantity of sewage flowing amounted to about 3.0 gallons per minute, which is quite small. However, it is within the range of average domestic sewage contribution from any industry which is stated to vary from 8 to 25 gallons per capita per shift.(1) Calculations based on this criteria resulted in flow rates varying from 1.5 to 4.2 gallons per minute. Details are shown below:

Number of employees per shift	Time Schedule
Shift NO. 1 - 220	07.00 - 15.00 hrs.
" 2 - 25	15.00 - 23.00 hrs.
" 3 - 25	23.00 - 07.00 hrs.
Total 270	24 hours

Therefore, the average maximum daily flow expected $= \frac{270 \times 25}{24 \times 60} = 4.2$ g.p.m.

and, the average minimum daily flow expected $= \frac{270 \times 8}{24 \times 60} = 1.5$ g.p.m.

(1) "Design and Construction of Sanitary and Storm Sewers," Manual of practice No. 9, WPCF; Manual of Engineering Practice No. 37, ASCE. (1959). p. 21.

The rate of flow, as noticed in the existing sewerage system,was not constant. It varied largely within the period of 8-hours starting at 8.00 a.m. as shown in Figure 3.1. This 8-hour flow curve is extended to include the rest of the working hours, assuming the flow remains unchanged after shift No. 1. The peak occurs at launch time. Its value, based on the data obtained, amounted to 250% of the average daily flow, i.e. 7.5 gallons per minute.

The existing network of sewers in the system is satisfactory from the sanitary and engineering point of view. Maintenance is good, and the capability of serving the refinery is adequate. It is also capable of handling any anticipated increase of flow throughout the next fifteen years without any shortcoming. This prediction is sound and is based on the following facts:

a) The expected increase in flow, throughout the stated period, depends on the increase in number of employees.

b) The increase in number of employees in closely related to the refinery plans for expansion.

c) Assuming that the refinery policy and capacity increase are to continue during the next 15 years as they did during the last 10 years, then from past and present employment figures,[2] the anticipated increase in number of employment is predicted to be 45 in the year 1980, as shown in Figure 3.2.

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[2] Medreco - Sidon Refinery. Personnel Manager; Personal Communication.

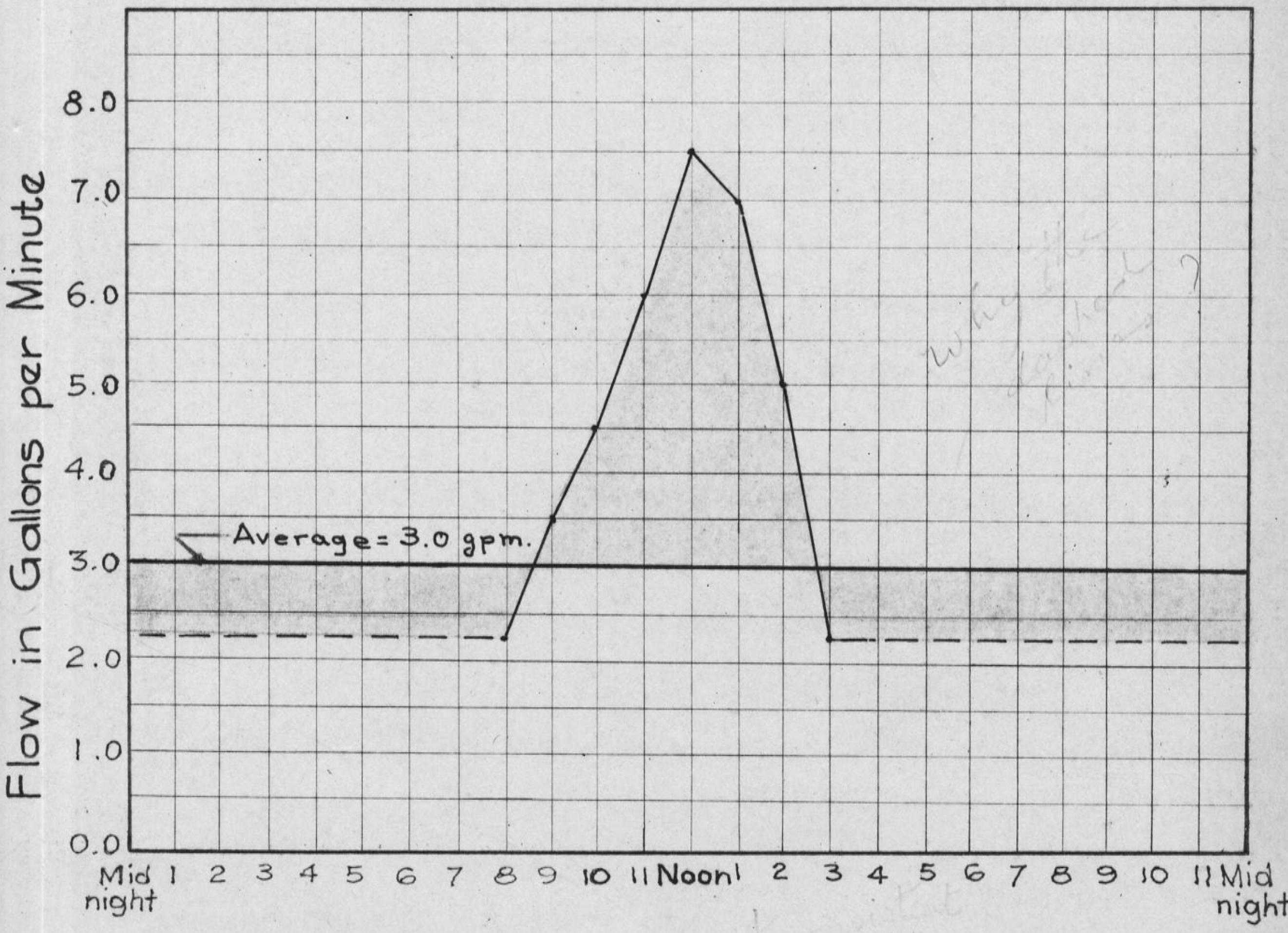

Figure 3.1. Hourly variation in sewage flow.

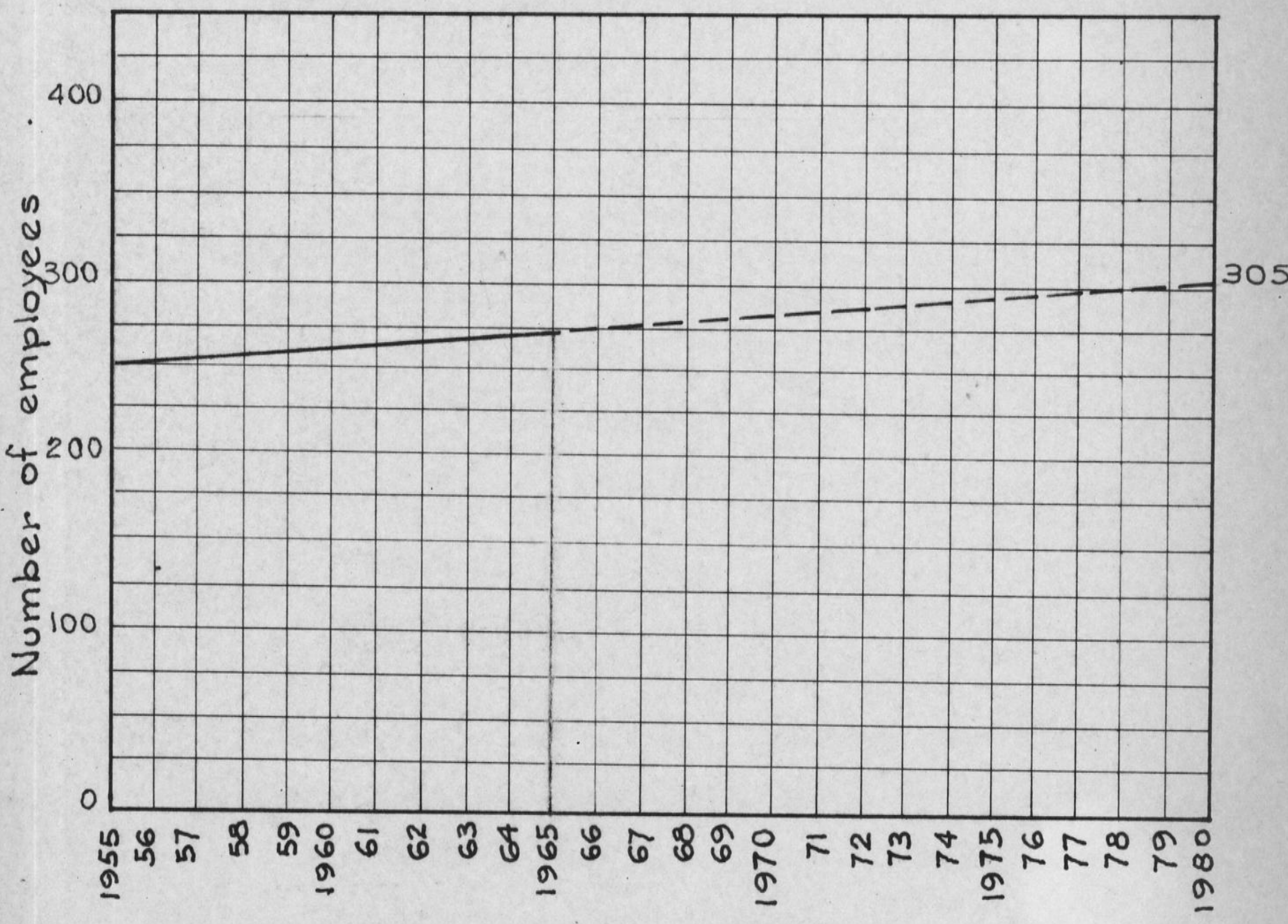

Figure 3.2. Anticipated increace in employment

With a total increase of 45 employees in 1980, the anticipated increase in sewage flow is quite small and insignificant. Hence, the existing network of sewers is considered to be adequate.

2.1.2. Quality of Sewage

The quality of raw sewage based on laboratory analysis for a sample composited over a continuous 8-hour period on May 4, 1965 is shown in Table 3.1.

Table 3.1. Raw Sewage Analysis

Characteristic	p.p.m.
Total Solids	640
Suspended Solids	310
Volatile Solids	180
5-day B.O.D.	290
Chloride, as Cl	60

From the analytical results, it is observed that the raw sewage has an average-strength characteristics of domestic sewage and this value is expected to be maintained as long as the rate of water consumption for domestic purposes remains unchanged.

3.1.3 Sewage Treatment

The two septic tanks now in operation have almost no practical influence on the reduction of its pollution potential. The effluent leaving the tank is offensive in character and potentially dangerous to health. The hourly variation in reduction of contaminants passing through the septic tanks is presented in Figure 3.3. The efficiency of the tanks in removing suspended solids amounted to about 40% compared to over 60% expected from a well designed single chambered septic tank.[3]

At first, the Refinery had installed the small septic tank measuring 15 feet long, by 8 feet wide, and 5 feet water depth. When placed in operation, sludge accumulated in excessive amounts on the bottom and filled the tank more quickly than desired. As a result, the Refinery provided a larger tank to operate in parallel with the first. The new tank measures 25 feet long, 8 feet wide, and 5 feet water depth. Both tanks are single-chambered with ample capacity to allow sludge storage for disludging every three years, and an additional volume equal to a retention period of 2 days for an average daily flow of sewage of 3 gallons per minute. The average accumulation of sludge in the tank is expected to be 0.92 ft^3/person/year[4].

The tanks are burried about 5 feet below ground level, with walls around the manhole extending above tank surface to prevent the entrance of surface runoff to tanks.

Further details of design and construction cannot be presented because the necessary drawings are not available.

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(3) V.M. Ehler, and E.W. Steel, Municipal and Rural Sanitation, 4th ed. McGraw Hill Book Company Inc., New York 1950, p. 46.

(4) Ibid., p. 46.

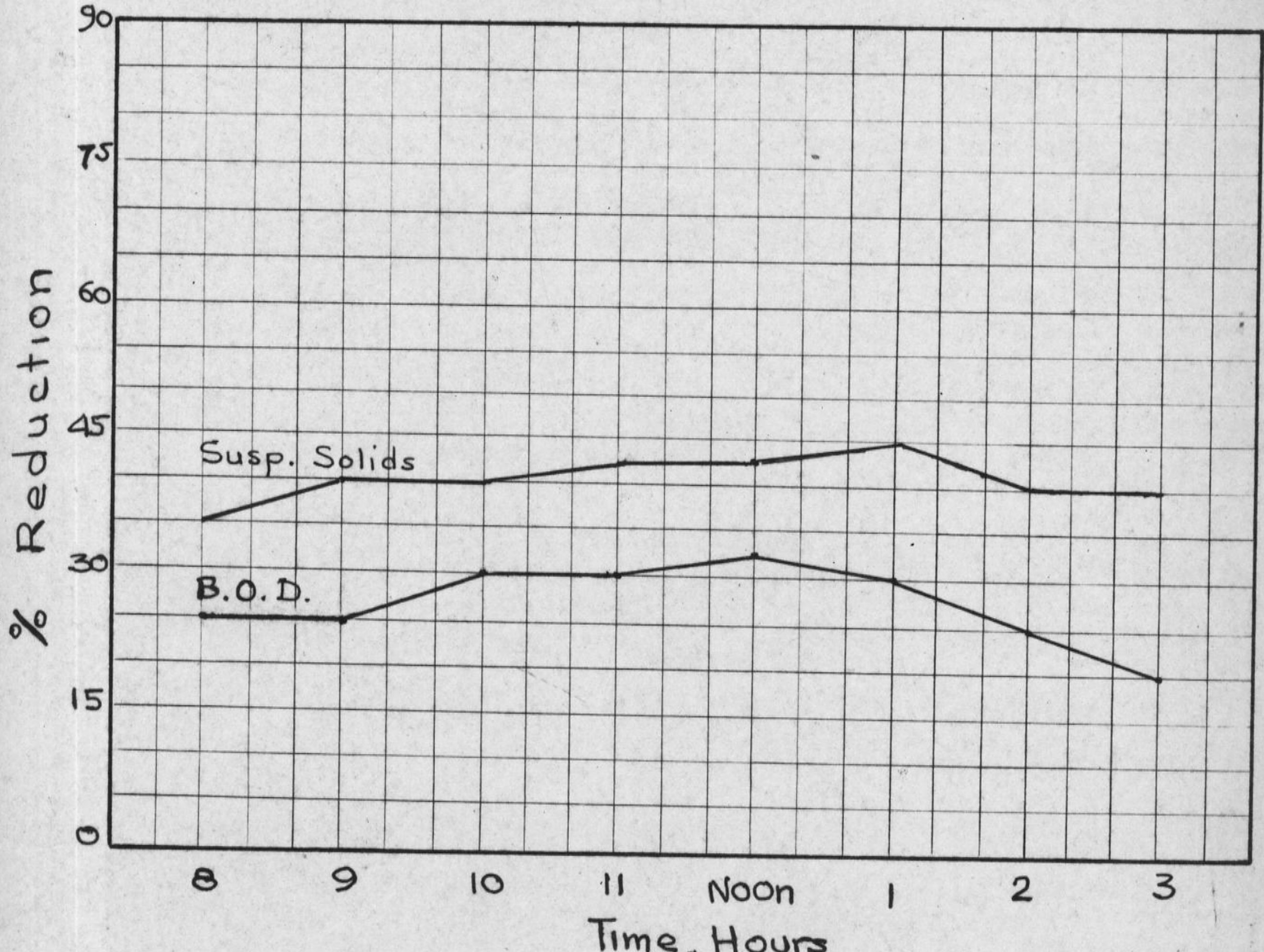

Figure 3.3. Reduction of contaminants passing through the septic tanks.

3.2. Process Waste Water System

3.2.1. Quantity of Process Waste Water

The process waste water is mainly composed of process water and oily water. In detail, these wastes derive from crude distillation and distillate treating operations, tank-bottom water drawoffs, some cooling water, some water condensate from steam facilities, and oil contaminated rainfall runoff. Auxiliary sources which add to the total waste water stream are garages, mechanical shops, and the chemical laboratory.

The quantity of flow from all these sources varies from day to day and even within a given day. In this survey, it is assumed that the flow rates in the refinery do not vary appreciably from day to day, and a one day flow record is also assumed to suffice the purpose as a basis for design.

Under present conditions, an estimate of the amount of waste water cannot be derived from the quantities of water consumed in process operation because of the missing records on water supplies. However, actual flow by measurement over a continuous 8-hour period carried on May 11, 1965, indicated an average daily flow of 390 gallons per minute, and a peak of 500 gallons per minute (Figure 3.4.). The technique used in measuring the flow rates is the same as that used in measuring domestic sewage flows described earlier, except that the distribution box of the system was used as a substitute for the bucket.

On comparing the measured flow rates with those expected from a refinery showing values varying from 800 to 1830 gallons per minute,

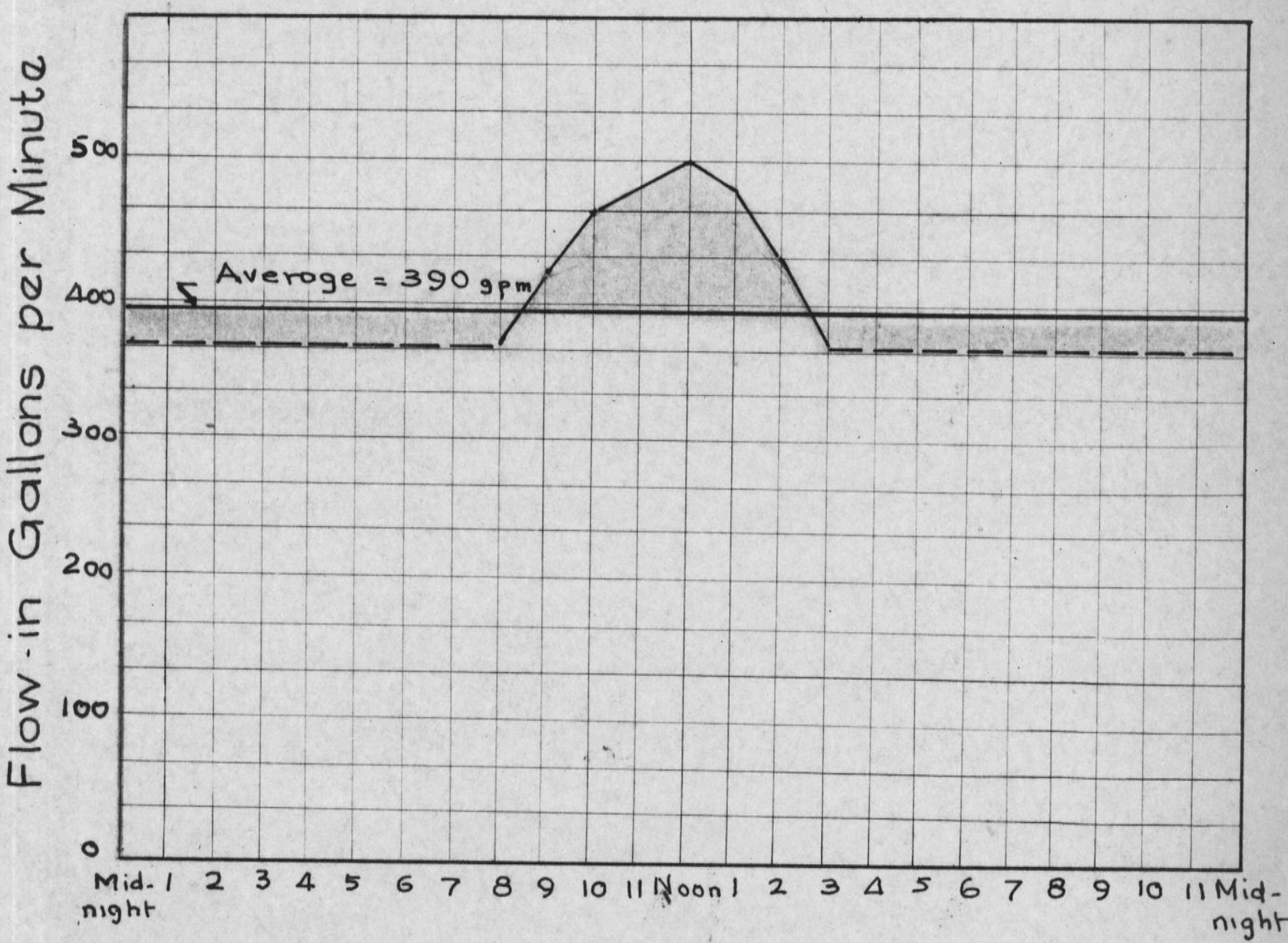

Figure 3.4. Hourly variation in process waste water

it is difficult to correlate them and the difference is believed to be due to the limited range of products manufactured in the refinery under study. Calculation of the expected flows is based on the following criteria:

Process waste water flowing from oil refineries average 700 to 800 gallons per barrel of oil processed, and if the water is not reused the cooling water amounts 80% to 90% of the process waste water volume.(5)

Hence, with the present nominal input capacity of 16,500 barrels a day in Sidon Refinery where the cooling water is recirculated, the expected values are calculated as follows:

a) The maximum expected process waste water $= \frac{16500 \times 800 \times 0.20}{60 \times 24}$

$= 1830$ g.p.m.

b) The minimum expected process waste water $= \frac{16500 \times 700 \times 0.10}{60 \times 24}$

$= 800$ g.p.m.

For the design works to follow, it is assumed that the field figures are valid and acceptable.

3.3.2. Process Waste Water Quality

In view of the great variation in the quantity of water used at the Sidon Refinery, it is not surprising that the contaminants level and characteristics of the waste waters also vary widely from hour to hour and from day to day.

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(5) E.E. Seelyee, Data Book for Civil Engineers - Design. Vol. 1, 2nd edition, John Willey and Sons, New York, 1953. p. 5-96.

The process waste water carries varying amounts of suspended matter and oil which forms films on the water surface thus causing unaerobic conditions that result in the production of abnoxions odors. Composite samples were collected over a period of 8-hours from various points of the treatment plant on May 6, 1965; laboratory analysis, carried on the same day, gave results shown in Table 3.3. The ~~figures~~ Table indicate that most of the oil and settleable solids in the final effluent are greatly removed as might be anticipated, and that the two substances that cause maximum trouble and pollution - the phenol and the waste oil - have inobjectionable limits of concentration in the final effluent. On comparing the values obtained with the requirements of Ontario Water Resources Commission, Canada, whose objectives for water quality for refinery effluent are listed in Table 3.2.,(6) it is probably safe to say that the objectives set forth by the Sidon Refinery to control water pollution are being met.

Table 3.2. Objectives for Water Quality for Refinery Effluent+

Characteristics	ppm (max.)
Phenol	0.002
Oils	15
5 day B.O.D.	15
Suspended solids	20

+ Requirements of OWRC, Canada.

(6) G.C. Campbell, and G.R. Scoullar, "Effluent Water Treating Facilities at Oakville Refinery". A preprint paper presented to the 29th. midyear meeting of the American Petroleum Institute's Refining Division, May 1964, p.l.

Table 3.3. Analysis of Process Waste Water

Analysis		Raw Process Waste Water	Primary Separator Effluent	Secondary Separator Effluent	Hay Filter Effluent
Odor		Noticeable	Moderate	Moderate	Slight
Temperature	°F	85	85	84	84
pH		7.0	7.0	7.0	7.0
Oil	ppm	39.4	15.5	11.4	10.2
Total Solids	"	610	400	320	280
Suspended Solids	"	390	330	270	240
Chloride, as Cl	"	370	350	330	310
Sulfate, as SO_4	"	19	18	18	17
Phenol	"	0	0	0	0
B.O.D.	"	5.7	5.0	4.1	3.1
Total Hardness, as $CaCO_3$	"	426	410	400	380
Total Alkalinity," "	"	290	270	270	250

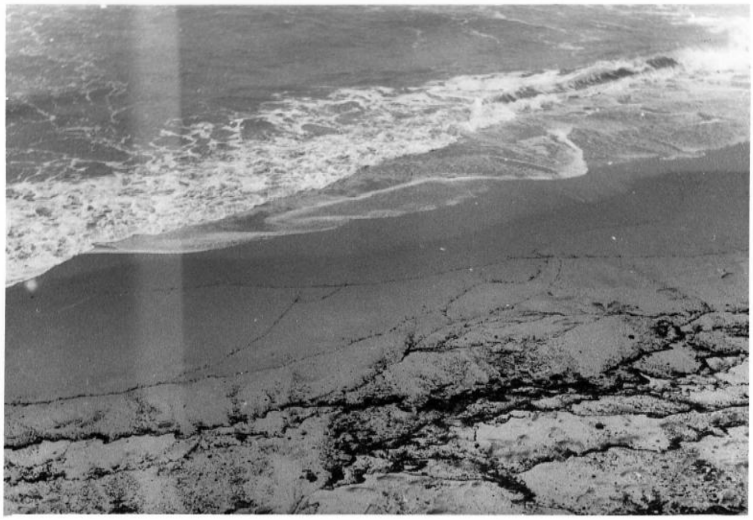

Figure 3.5. Tar deposits on the Beirut beach after a storm during the winte r of 1963, filmed by Prof. A. Acra.

The presence of 10.2 ppm of oil in the final effluent may not be detrimental to aquatic life and to persons using the water, because the very thin films of oil formed on water surface will disappear in a limited time by the operation of natural phenomina. It is indicated that oil may be discharged into surface waters at the rate of 10 gallons per hour per square mile without being visible to the eye, provided the distribution is uniform over the entire area.(7) Therefore, it is reasonable to assume that the $\frac{10.2 \times 380 \times 60}{1,000,000} = 0.23$ gallons per hour of oil discharged to the sea will either disappear, provided the distribution is uniform, or disperse by the wind, current, and wave action and deposit on the shore, forming tar balls. The two films shown in Figure 3.5., present a clear picture of the situation existing usually on shores of Lebanon.

3.2.3. Process Waste Water Treatment Units

A primary process of waste treatment by gravity separation is used. Secondary processes, to achieve further separation or elimination of undesirable components in wastes water, include filtration and final disposal by dilution. The units adopted for such processes include:

a) Gravity-type oil-water separator.

A survey of the separators now in operation disclosed that they are not so effective as might be desired. The refinery installed the primary separator first. When placed in operation, it removed considerable quantities of oil and other suspensions but the effluent still carried oil in objectionable quantities. The secondary separator was then provided to

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(7) American Petroleum Institute, Manual on Disposal of Refinery Wastes, Vol. 1, Waste Water Containing Oil, 7th edition, 1963, pp. 10-11.

operate in series with the first. This second unit provided practically very little additional oil removal because the oil carried through the first separator is either in an emulsified state or adhering to other suspended particles so that the combination remains in suspension neither setting nor floating. This is a fact best verified by referring to Table 3.3. and calculating the effectiveness of the two separators in removing oil from waste water:

$$\text{Primary separator effectiveness} = \frac{39.4 - 15.5}{39.4} \times 100 = 61\%$$

at a removal rate of 12.4 gallons per day.

$$\text{Secondary separator effectiveness} = \frac{15.5 - 11.4}{15.5} \times 100 = 27\%$$

at a removal rate of 2.2 gallons per day.

$$\text{Overall separators' effectiveness} = \frac{39.4 - 11.4}{39.4} \times 100 = 71\%$$

at a total removal rate of 14.4 gallons per day.

It is readily apparent that the secondary separator has little practical value in removing oil, and that any improvement in the effectiveness of the primary separator does not necessitate the existance of the secondary separator.

The separators are located at a point of low elevation which insures drainage of the entire system by gravity. They are of the old type with no provision for continuous cleaning and removal of sediment which, if permitted to accumulate in excessive amounts, will result in unsatisfactory functioning of the separators. This situation arises especially in the stormy days where rainfall runoff carries excessive amounts of silts to the separator, and as a consequence, sediments increase, efficiency and detention time decreases, and some oil with other floating materials are carried by the effluent to the sea in objectionable quantities. In an effort to overcome this problem, frequent cleaning is required - at present the separators are cleaned only twice a year. Besides, other current and anticipated operational problems to be pointed out later necessitate installation of a separator of new and improved design to replace the existing two separators.

A predesign investigation to obtain the necessary data upon which to base a detailed design for the new separator resulted the following characteristics of waste water and oil:

a) Waste Water:

Temperature	(T)	=	$85^{\circ}F$
Specific gravity	(Sw)	=	0.998
Absolute viscousity	(μ)	=	0.0057 poise

b) Oil globules in waste water:

Diameter of globule, (estimated)	(D)	=	0.015 cms.
Specific gravity	(So)	=	0.846

Complete account of the procedure used in establishing the design basis for the separator is discussed in the next chapter.

b) Hay Filter

The hay filter removes little or no sediment unless the hay medium is continuously removed and uniformely placed. It is expensive to operate and maintain; however, under proper conditions it may be practical to utilize and to maintain them properly to best advantage.

The hay medium is placed in two hay baskets arranged so that there is no leakage around or over the basket and so that baskets may be changed one at a time without allowing for flow of unfiltered effluent.

The existing hay filter is not effective in oil removal at all times because the frequency of replacing the filter medium is not well controlled. At times, when the medium becomes saturated, absorption ceases and oil escapes with the effluent into the sea.

From the data in Table 3.2. the effectiveness of the filter oil averaged $\frac{11.4 - 10.2}{11.4} \times 100 = 10\%$, or 0.6 gallons per day which is low and insignificant compared with its cost of operation.

c) Detention Pond

The primary oil separator is designed to handle a maximum flow of 400 gallons per minute. Extra flow is collected in a detention pond and recharged to the separator when the flow returns below 400 per minute. The pond, having a capacity of 600 gallons per minute for 4 hours, seems to be an economical means of reducing the capacity of the separator, but at the same time it is a source of headache because of solids accumulation, intense odor production, and exposure of a large surface area of oil giving rise to air pollution and fire hazards. In addition, an appreciable ground area is occupied.

It is recommended that the existing detention pond be eliminated and the waste water be treated without detention. The net result will be a new separator design which can handle all process water and contaminated waste water, yet not greatly overdesigned for dry weather flows.

3.3. Storm Water and Drainage System

This part of the design criteria contains the principal data related to the hydrology of Sidon area covering the refinery site. The data was collected and analysed to determine the magnitude, character and distribution of rainfall, in addition to the amount, type and characteristics of runoff. The basic assumption made and the results obtained are discussed in detail hereunder.

3.3.1. Hydrological Data

Sidon is located on the eastern shore of the mediterranean sea. It has a moderately cold, windy, and wet climate in winter, and is warm and dry in summer and fall. In Sidon, precipitation is produced as a result of orographic lifting of the moisture bearing winds blowing from west across the Mediterranean Sea. This orographic lifting over the Lebanese mountains is such that the heaviest precipitation occurs in the west side of the mountains covering the refinery site.[8]

Due to the lack of rainfall records or meteorological stations in the refinery and vicinity, the American University of Beirut Observatory precipitation records and information regarding rainfall characteristics are utilized as a substitute. The justification for such an action is based on the fact that the climate in Sidon has similar characteristics as that in Beirut.

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(8) U.S. Dept. of Interior, Bureau of Reclamation, Reconnaisance Report, Water Resources Investigation for the Nahr Arka Basin-Republic of Lebanon. Report No. 2 Danver, Columbia, Sept. 1956. p. 111-1 .

Total rainfall records for the past 88 years starting in 1877, available at the American University of Beirut Observatory indicated an average yearly rainfall of about 34.5 inches and a maximum rainfall of 47.0 inches recorded in 1878.

From details of the rainfall records accumulated over a period of 8 years, the relation between duration and intensity is plotted on a curve as shown in Figure 3.6. This curve is an important tool for the prediction of rainfall.

3.3.2. Surface Runoff

The rate of surface runoff is difficult to estimate accurately, Runoff formulas giving satisfactory results are numerous in practice. A discussion of all of these is outside the scope of this study.

With the available information, the most suitable methods that will give satisfactory results for the locality, is the "rational method". It translates rainfall into runoff by the formula:

$$Q = C I A$$

where,

Q = Runoff in c.f.s.
A = Area of watershed in acres.
I = Intensity of rainfall in inches per hour
C = Coefficient of runoff.

The foregoing factors are accounted as follows:

a) The area contributing to the point under consideration - separator area - is marked on the plan of the refinery as shown in Drawing No. 1 (Appendix). The complete drainage area is subdivided in two component parts tributory to the design point. These are:

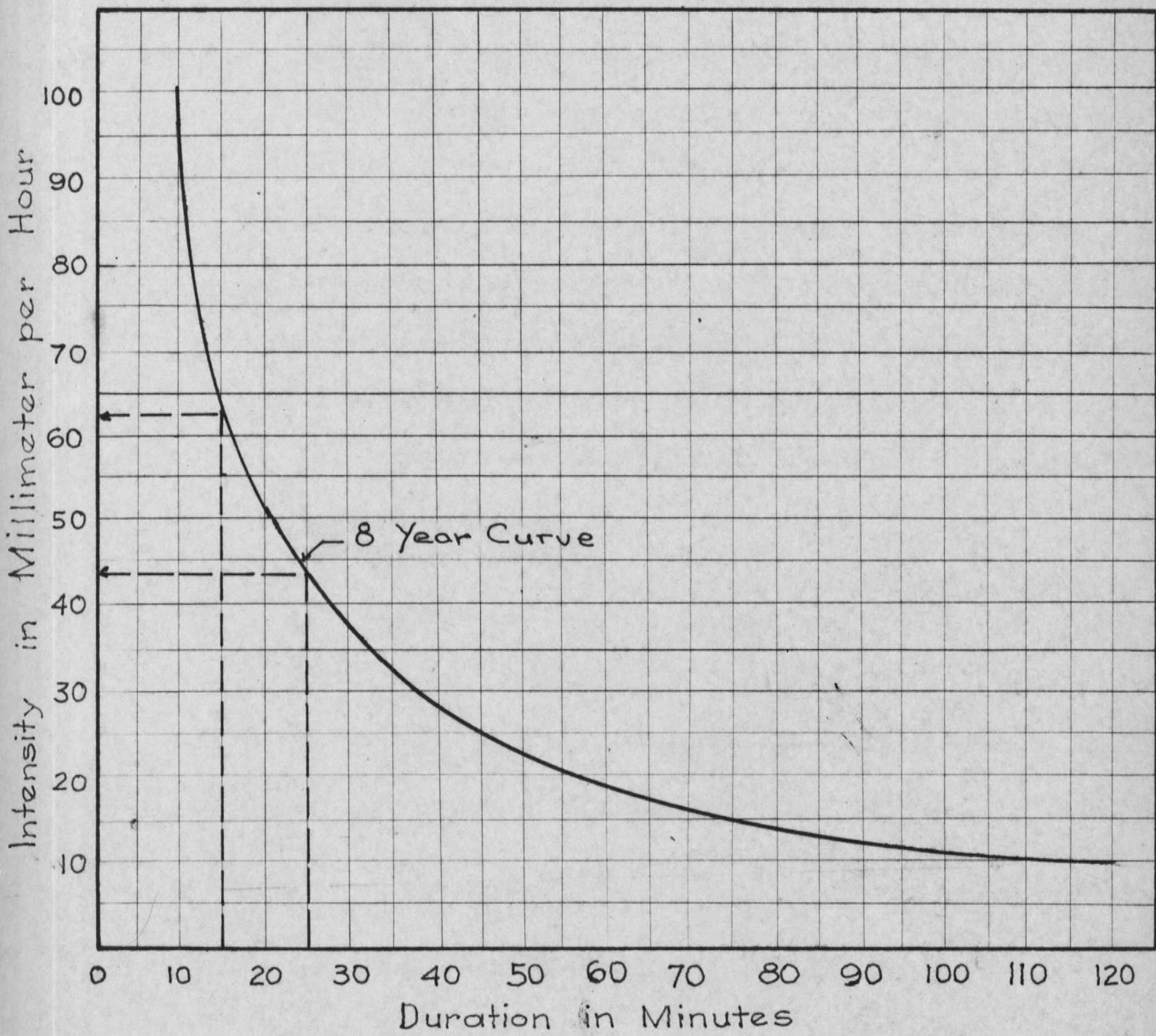

Figure 3.6. Rainfall curve derived from storm records+

+

$$\text{Tank year area} = \frac{200 \times 125}{4047} = 6.2 \text{ acres}$$

$$\text{Process area} = \frac{140 \times 140}{4047} = 3.0 \text{ acres}$$

b) The fact that most of the process area is properly developed, it prompts the adoption of an average runoff coefficient value of 0.90. As for the tank yeard area, where the earth surface is clayey and sandy, an average value of 0.40 seems to be satisfactory.[9]

c) The fact that the area used for drainage of contaminated rainfall runoff is composed of two sectors, located at different distances from the point where the design of separation is considered, different times of concentration are estimated for each section while the corresponding rainfall intensities are derived from Figure 3.5.

Area	Time of concentration			Rainfall
	Inlet time[10] min.	Flow time min.	Total min.	Intensity mm/hr.
Tank Yard Area	10	15	25	44
Process Area	5	10	15	64

(9) E.E. Sealyee. Data Book for Civil Engineers - Design Vol. 1, 2nd edition, John Wiley and Sons, New York 1953, p. 5-01 .

(10) Design and Construction of Sanitary and Storm Sewer; Manual of Practice No. 9. WPCF; Mnual of Engineering Practice No. 37, ASCE (1959), p. 46.

The time of concentration in each area is made up of the inlet time, which is the concentration for each area in which the sewer starts, and time of flow in the sewer to the separator location.

Applying all the values determined above in the rational formula, the surface runoff is calculated as follows:

$$\text{In the tank yard area} = \frac{0.40 \times 44 \times 6.3}{10 \times 2.58} = 4.3 \text{ c.f.s.}$$

$$\text{and in the process area} = \frac{0.90 \times 64 \times 3.0}{10 \times 2.58} = 6.7 \text{ c.f.s.}$$

These large quantities of surface runoff that exceed the capacity of the sewers at the maximum flow rates have the advantage of diluting process waste water and reducing oil concentration.

3.4. Water Supply System

3.4.1. Water Quality

The refinery is not very demanding as regards the quality of the water it uses. It needs water of drinking quality for domestic uses and softened water for the production of steam; but for its other large quantity - low quality services it is satisfied with water which does not contain too high a concentration of salts and more than 1000 g.p.m. of dissolved solids.(11)

In checking the quality of the well water reference was made to a complete analysis on samples conducted on May, 1965 by the Refinery. The results, given in Table 3.4, were confirmed in June 1965.

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(11) National Association of Manufacturers, Water Use in Industry, A Survey of Water Use in U.S. Industries, New York, 1965, pp. 44-45.

Table 3.4. Analysis of Well Water

Analysis		Well # 1	Well # 2	Well # 3
pH		7.6	7.2	7.6
Total Alkalinity, as $CaCO_3$	ppm.	260	265	260
Hardness, as $CaCO_3$	"			
a) Total	"	295	300	480
b) Temporary	"	275	275	275
c) Permanent	"	20	25	205
d) Calcium	"	165	175	335
e) Magnesium	"	130	125	145
Chlorides, as Cl	"	90	130	100
Iron, as Fe	"	0.22	0.31	0.27
Silica, as SiO_2	"	8.0	9.0	10.0
Total Solids	"	380	409	689
Sulfate, as SO_4	"	13.1	18.9	20.3
Phosphate, as PO_4	"	Nil	Nil	Nil

The results of the analysis indicate that the quality of water is rather hard and free of pathogenic bacteria. The hardness is undesirable because heating or evaporating produce hard stony scale deposits that clog fluid system and cause damage. Hence, the water used for generating steam is passed through a hot-process lime softeners to remove hardness. For other uses the water is used without treatment. As far as the chloride content of raw water, there is no evidence of sea-water intrusion at present. This is mainly because the pumped quantity of water from the aquifer is not exceeding the safe yield of the ground water basin.

3.4.2. Water Quantity

Because complete flow data on water pumpage is not available, an accurate estimate of the average daily use of water is not possible. However, an estimate of the total quantity of water consumed at the refinery may be derived from the waste flow values for the total water consumption should be in reasonable agreement with the sum of all waste outflows. The correlation is not usually good on an instantanious basis, but should check well with flows over a prolonged period of days and weeks.

An approximation of the water consumption, based on rates of waste water flows determined over a period of several hours, totaled about 1200 gallons per minute and is accounted as follows:

Process waste water	390.0 g.p.m.
Domestic sewage	3.0 "
Cooling water losses	630.0 "
Other water losses (seepage)	47.0 "
Total	1200.0 g.p.m.

The estimate for cooling water losses through windage and evaporation is stated to vary in the range of 50-60 gallons per barrel of oil processed.[12]

(12) Ibid., p. 44.

As regards the quantity of available under ground water, adequate information is lacking to provide a reliable estimate, or to give a quantitative answer as to their potentialities or limitation for development.

While at present the supply can meet the refinery demands satisfactorily, it is anticipated that with the high consumption and continuous pumpage of ground water deterioration in quantity and saline water infiltration may ultimately become a reality. Many instances throughout the world could be cited to emphasize the gravity of such an anticipated situation. In California, for example, the intensive use of surface supplies, and over pumpage of ground water, mostly since 1940, it has led to declining water table and, in many coastal areas, to a loss of producing aquifers to intruding sea water.[(13)] Therefore, to overcome this potential problem in the Sidon Refinery, modifications in the existing waste treatment plant are being introduced whereby substantial quantities of water that are now discharged to the sea are being conserved.

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(13) "Studies in Water Reclamation"; Technical Bulletin No. 13, Sanitary Engineering Research Laboratory, University of California, July 1955, p. 59.

With the completion of the plant survey, the sanitary engineering task of developing solutions to all problems encountered begins. The task divides itself logically into three major parts:

a) Modification of treatment facilities to prepare wastes of better quality for disposal.

b) Reduction of waste quantity and pollutional load to the acceptable limits, and

c) Utilization of water as effectively as possible.

A detailed account of the developed solutions to all problems encountered is presented in the text.

4.1. Domestic Sewerage System

The sewage treatment system, which has been in operation for the last 10 years, has proved to be well suited to the needs of the refinery. However, the inefficiency of the septic tank is treating the sewage - believed to be due to the improper design and poor maintenance - is the only problem encountered in the system

From Figure 3.3. the 40 percent removal of suspended solids and the 25 per cent reduction in B.O.D. are, comparatively, much less than the 60-70 percent removal of suspended solids and the 40 per cent reduction in B.O.D., expected from the well designed and maintained, similar single-chambered septic tank.[1]

(1) V.M. Ehler, and E.W. Steel, Municipal and Rural Sanitation, 4th ed. McGraw Hill Book Company Inc., New York. p. 51.

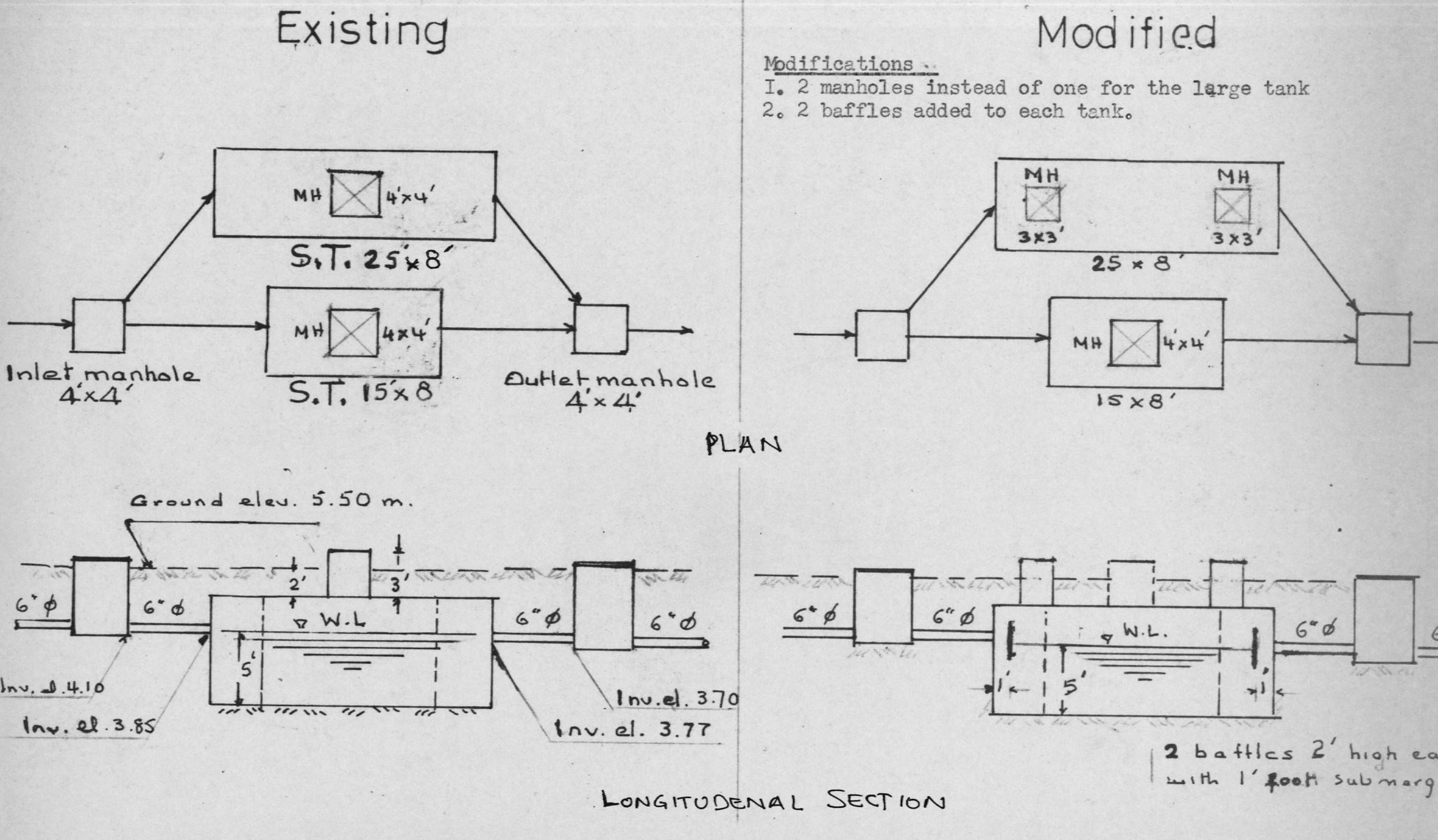

Figure 4.1. Details of septic tanks

Figure 4.1. shows details of the existing two septic tanks compared with details of the same tanks modified for better operation and greater efficiency. All changes and modifications introduced are based on simplicity, ease of installation, and the possibility of getting maximum advantage of the existing tanks. Baffles are introduced to avoid turbulance and reduce short circuiting of sewage flow. Two manholes are placed for the larger tank to facilitate maintenance and cleaning activities. However, with the changes introduced, it is still believed that the septic tanks effluent remains polluted. Dissolved solids still remain, together with particles of sludge decomposition. Bacteria are expected in great numbers. The effluent, however, requires no further treatment to render it inoffensive, because of the practice of discharging the effluent offshore into the sea and diluting it with large quantities of sea water.

4.2. Process Waste Water System

Although the existing process waste water treatment units have shown 75 per cent effectiveness in oil removal, the situation has required that a new system be investigated in an effort to meet the future expansion requirements of the refinery, to effectively remove all oil and settleable as well as floated materials, and to lower the cost of waste water reclamation following gravity separation.

An overall picture of the proposed solutions includes:

a) Design of a new gravity separator with adequate capacity,

b) Design of a reclamation plant capable of upgrading and purifying the separator effluent for reuse, and

c) Recommendations for the proper disposal of all solid wastes.

4.2.1. Gravity-Type Oil-Water Separator Design Parameters

A new gravity-type oil-water separator is proposed to replace the two separators now in operation. It is designed for:

a) A continuous collection and disposal of settled sludge.

b) A maximum oil recovery for return to refinery processes, and

c) An adequate treatment and handling capacity.

The design is based on the following three minimum requirements recommended by the American Petroleum Institute:[2]

i) A minimum total horizontal area (A_h, square feet) based on flow of waste water (Q_w, cubic feet per minute), rate of rise of an oil globule 0.015 cm. in diameter (v_t, feet per minute), and a factor, F, to correct for turbulence and short circuiting.

$$A_h = F \frac{Q_W}{v_t} \qquad \text{———— 4.1}$$

The value of v_t for a 0.015 cm. globule is derived from Stokes law, and has been modified for petroleum waste into the following expression, based on the specific gravities (S_w and S_o) of turbid waste and waste oil at actual flow temperature and the absolute viscousity of turbid waste (μ poise) - also at the design temperature.

$$v_t = 0.0241 \frac{(S_W - S_o)}{\mu} \qquad \text{———— 4.2}$$

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(2) American Petroleum Institute, Manual of Disposal of Refinery Waste, Vol. 1, Waste Water Containing Oil, 7th edition, 1963. pp. 18-20.

The design factor, F, is the product of a short-circuiting factor (recommended as 1.2) and a turbulance factor depending on the ratio of $\frac{V_h}{v_t}$.

ii) A minimum vertical non-sectional area (A_c, square feet) based on the flow of waste water (Q_w) and the horizontal flow velocity (V_h):

$$A_c = \frac{Q_w}{V_h} \qquad \text{———————} \quad 4.3$$

The value of V_h should not exceed 15 times the rising velocity v_t and should not be more than 3 feet per minute.

iii) A minimum ratio of depth to width of 0.3. There is no objection to values of about 0.5 for this ratio, if economics so dictate.

In addition to these three recommendations the fourth principal factor considered in designing the separator is the prediction of the average daily flow rates of process waste water for a design period selected to be 20 years.

4.2.2. Probable Future Waste Water Flow

To develop the probable future process waste water quantity, it becomes necessary to predict the future crude oil input capacity in the refinery.

From Table 1.1. the graph of Figure 4.2. is plotted. It shows an average increase of 265 thousand barrels of crude oil input per year, which when projected linearly to the year 1985, gives an input capacity of 10,965 thousand barrels a year, or 23,300 barrels a day. Hence, while assuming that the process waste water is in direct proportion with the crude oil input rates, and refering to Figure 3.4. then the predicted:

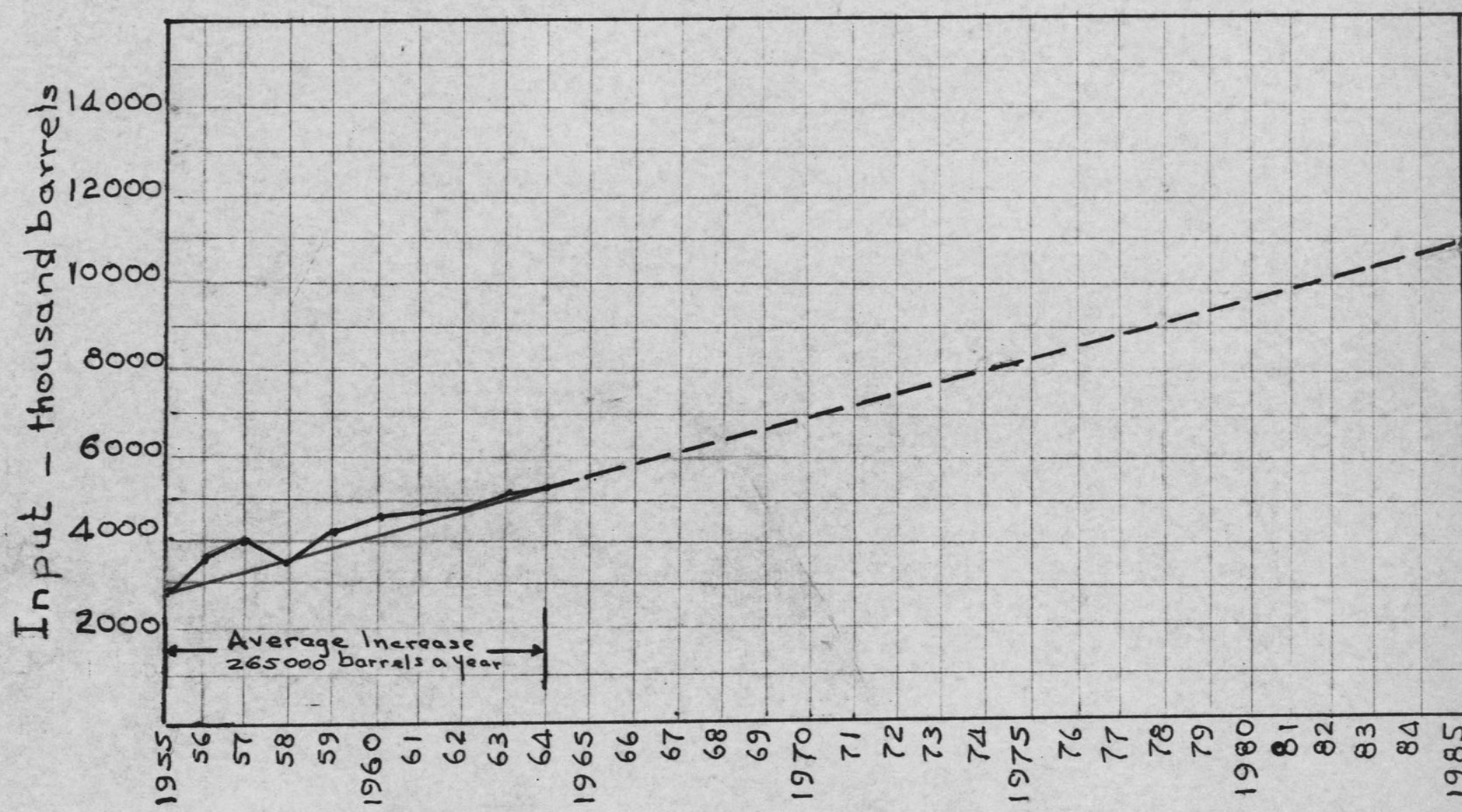

Figure 4.2. Predicted crude oil Input capacity.

$$\text{Daily average waste water flow} = \frac{23300}{16500} \times 390 = 660 \text{ gallons per minute}$$

$$\text{Daily minimum waste water flow} = \frac{660}{390} \times 365 = 621 \text{ " " "}$$

$$\text{Daily maximum waste water flow} = \frac{660}{390} \times 500 = 850 \text{ " " "}$$

This projection to future flows may not be satisfactory and give rates that may become lower than the actual flows when future conditions are reached. Therefore, a contingency factor of 40 gallons per minute is added to the flow rates predicted. This factor allows for infiltration of ground water and any unforseen activity which might take place in future. Moreover, since part of the rain water runoff is collected in the same sewer system for process waste water, then the final design flow rates should include this part of runoff too. But, because the existing sewers are approaching their full capacity with a flow rate of 1,000 gallons per minute, then the new separator is designed to handle a maximum total flow of 1,000 g.p.m. corresponding to the full capacity of the sewers.

Excess rain water runoff above the capacity of the sewer is handled as follows:

a) In the tank yard area, excess rain water runoff is impounded in the same basin, and ultimately drains to the sewer line when flows drop below normal.

b) In the process area, surcharges collected in open ditches by-passing the treatment plant, and directly discharge to the river.

4.2.3. Design of Separator

Applying the data presented in Section 3.2.3. to equation 4.2. the rate of rise of oil globule in waste water is computed as follows:

$$V_t = 0.0241 \left(\frac{0.998 - 0.846}{0.0057} \right)$$

$$= 0.643 \text{ feet per minute.}$$

The horizontal velocity of flow

$$V_h = 15\ V_t$$

$$= 15 \times 0.643$$

$$= 9.64 > 3.0 \text{ feet per minute maximum allowed on per}$$

requirement (ii).

Therefore $V_h = 3.0$ feet per minute,

From equation 4.3. the minimum vertical cross sectional area of the chamber

$$A_c = \frac{1000}{3} \times 0.14$$

$$= 47 \text{ square feet.}$$

For the effect of turbulance, where $\frac{V_h}{V_t} = 4.67$, the factor F (turbulance) = 1.11.[3]

Therefore, from equation 4.1, the minimum horizontal area (A_h) is computed

$$A_h = (1.2 + 1.1) \left(\frac{1000}{0.643} \right) \times 0.14$$

$$= 510 \text{ square feet.}$$

Though the calculations indicate that one larger channel could be sufficient, it is recommended that there be two channels. Hence, with two channels, each 7 feet wide the depth of water should be:

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(3) Ibid., p. 20

$$d = \frac{A_c}{n \times B}$$

$$= \frac{47}{2 \times 7} = 3.5 \text{ feet.}$$

and the ratio

$$\frac{d}{B} = \frac{3.5}{7.0} = 0.5 \qquad \text{O.K.}$$

Having the width and depth established as 7.0 and 3.5 feet, respectively, then the length is computed from the equation:(4)

$$L = F \left(\frac{V_h}{v_t} \right) d$$

$$= 2.31 \times \frac{3.0}{0.643} \times 3.5$$

$$= 41.6 \text{ feet (say, 42 feet).}$$

Therefore, the final dimensions determined are:

Number of channels,	n = 2
Width of each channel.	B = 7.0 feet.
Depth of Water level,	d = 3.5 feet.
Length of channel,	L = 42.0 feet.

4.2.4. Details of Design

Having completed the design of the separator , the next step is a matter of adding structural details and defining the flow pattern.

Figure 4.3

Drawing No. 3 shows the arrangement and illustrates the process of gravity separation by the oil-water separator.

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(4) Ibid., p. 20.

The process waste water first enters the distribution chamber which splits and introduces the flow, equally through multiple ports into the inlet end of the two channels of the separator. At the inlet end, a vertical slot baffle is used to improve the hydraulic characteristics and retention performances of the separator. The baffle is made of pipes constructed so that the cross-sectional area of flow through the baffle is about 4 per cent of the cross-sectional area of the chamber, i.e., 7.0 x 3.5 x 0.04 = 0.98 square feet. With this recommended area, and with a horizontal velocity, V_h, of 3 feet per minute, the velocity of flow through the baffle will be 1.25 feet/second. This high velocity through the slots of the baffle is reduced to 3 feet/minute downstream in the channel proper. The 4 - per cent figure for clear area with slots $\frac{5}{16}$ inch wide, spaced at 8-in centers, each channel will accomodate 10 slots of the foregoing dimensions.

The channel proper is equipped with a 10-in slotted pipe skimmer for oil removal, and a flight scraper device that pushes settled solids from the bottom to sludge hoppers from which they are removed intermitantly by pumping.

The water at the effluent end passes under a vertical oil-retention baffle submerged 1.75 feet, then over a vertical sharp crested rectangular weir made of a plate fastened to the end wall of the separator. The weir extends upward to a height equal to the water depth of 3.5 feet minus the depth of normal flow, H, over the crest which is calculated by the simplified Francis formula:[5]

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(5) Ibid., p. 30.

$$H = \left(\frac{Q}{3.33\ L} \right)^{2/3} \qquad \ldots\ldots\ldots\ 5.4.$$

$$= \left(\frac{1000 \times 0.14}{60 \times 3.33 \times 15} \right)^{2/3}$$

$$= 0.13 \text{ feet.}$$

Therefore, the height of the weir equals 3.37 feet.

The effluent drawoff is a simple rectangular flume 3 feet wide, with a 15 in. diameter outlet.

4.2.5. Sediment and Oil Removal

Six hoppers are built into the floor of the channel immediately downstream from the distribution baffle. They are 2 feet deep, with side slopes of 45°. They have sufficient capacity to allow two days sediment accumulation, assuming 100 per cent effectiveness of separators in removing settleable solids from waste water at maximum flow rates of 1,000 gallons per minute.

$$\text{Volume of hoppers} = \frac{(4.0 \times 4.0)}{2} \times 2 \times 6$$

$$= 96.0 \text{ cubic feet.}$$

Volume of sediment per day (refer to Table 3.3.)

$$= \frac{(610 - 390)}{1000\ 000} (1000 \times 60 \times 24)\ 0.14$$

$$= 42.2 \text{ cubic feet}$$

Hence, a two days sediment storage is available.

The sediment slurry is to be removed, as slowly as possible from the hoppers, by pumping through a suitable sludge removal pipe 6 inch in diameter, using a plunger pump of suitable type. The slurry is pumped once every other day to the adjacent sludge basin for prolonged settlement and volume reduction.

The skimmed oil is conveyed by a 10-in horizontal skimming pipe to a sump tank installed on one side of the separator and below the separator operating level. The tank is equipped with a suction line to a pump used to convey the collected oil to storage tanks called slop tanks. The sump is designed to allow accumulation of 2 days skimmed oil, assuming 100 per cent separator effectiveness in removal of oil from waste water flowing at the maximum rate of 1,000 gallons per minute. In other words, the volume required:

$$V = \frac{39.4}{1000\ 000} \ (1000 \times 60 \times 24)\ 0.14 \times 2$$

$$= 16 \text{ cubic feet}$$

The sump selected has 3.5 x 3.5 x 3.5 feet dimensions. The extra capacity is to allow for water to escape to the sump associated with the skimmed oil. The skimmed oil is to be pumped, whenever the sump is full, to the adjacent slop tanks for storage, dewatering, and return to the refinery processing plant.

Considerations for detailed design of pumps would not be necessary since the pumps now in use for sediment slurry and skimmed oil removal can be re-used and added to the new separator.

4.3. Water Supply System

Water requirements in the refinery are constantly in the increase. With such anticipated increase in the supply and consumption and with no increase in the average rainfall, it is to be expected that the ground water resources in the area may become unable to meet the future water demands. Therefore, it is necessary to control the rate of consumption and to reduce it to minimum. Reduction can be effected by installing a closed circuit for the use of process waste water. In this way, the water is continuously recirculated, recovered, and reused.

Under the present conditions of extracting underground water the occurrence of salt water infiltration would not be a surprise situations are known to have accured recently in several wells located in south Lebanon which led to their abandonment. Two recent examples of deep wells being closed down are those belonging to Ein-el-Delbi Water Supply Authority - one in Damour, the other in El-Na'ema. More cases are expected, since the Lebanese Government appears not to have the legal power to prevent or control the exploitation and use of ground water resources in the area.

The present rules and regulations related to the right of the ground water, enacted about 40 years ago, are unsound and no more enforceable under present circumstances. However, the Government is planning for new ground water legislation regarding development, use, and conservation. One of the most important plans to achieve its objectives is to prevent over extraction of ground water.

Since the Government cannot enforce any new legal rights to control exploitation of underground water, and since fresh water shortage is anticipated, the two plausible preventive measures recommended for adoption at the Sidon Refinery are:

a) Conversion of saline or sea water into fresh water.

b) Reclamation of the water from process waste water that is now produced and discharged into the sea.

The second solution seems more feasible from the practical and economical point of view since the process waste water at the Refinery is an important source for the reclamation of water. It is not only that water would be produced but the reclaimed water could serve to alleviate the overdraft in the underground water basins and thus assist in preventing the encroachment of salt-water infiltration. Also, reclamation is an important factor in the abatement of sea water pollution.

In U.S. reclamation and reuse of water have been become of increasing interest since 1950. Examples of industries using reclaimed water on a large-scale are numerous. Two large-scale projects of this type are those operated; one by Kaiser Steel Mill at Fontana, California, and the other by an oil refinery in Los Angeles County, California.(6)

4.4.1. Water Reclamation

Good water, usable for practically all purposes, may be reclaimed from the process waste water at a cost no greater, and perhaps less, than the cost of converting saline or sea water. Of course, to determine whether reclamation is an economical means for obtaining water to the quality required by the refinery, it is necessary to evaluate the economics of reclamation. The reclamation costs include the costs for treating process waste water in <u>addition</u> to the costs which would have to be borne by the Refinery for treatment and disposal of the same waste alone. It is not possible to estimate the cost of reclamation at the moment, until

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(6) "Water Reclamation from Sewage and Industrial Waste" Technical Bulletin No. 4, Sanitary Engineering Research Project. University of California, March, 1961. p. 10.

the complete design of the system is established. However, the comparative cost for supplying fresh water by means of sea water conversion is of interest.

The cost of converting sea-water in major installations in United States has been lowered to less than $1 per 1000 gallons.[7] These costs still remain prohibitive in areas like Lebanon where only a small fraction of surface and ground water supplies have been exploited, unless the conversion rates become competetive. Hence, it is expected that the reclamation process is more economical at least for the present.

The water reclaimed is to be utilized directly for the operational purposes of the refinery such as: plant processing, boiler feed, cooling water, fire protection, air conditioning, plant clean-ups, sanitary uses, and miscellaneous other uses.

A simplified flow diagram illustrating the processes and the arrangement of the proposed reclamation plant is as shown in Drawing No. 3.

4.3.2. Reclamation of process waste water.

This part is concerned with the refinery effluent from the oil separator which requires additional treatment for upgrading, cleaning, and reuse. Oil, suspended solids, taste and odor are the objectionable materials and characteristics of the separator effluent, which seldom can be reused for refining purposes without complete purification. The principal processes used for purification include:

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(7) National Association of Manufacturers, Water Use in Industry, a Survey on Water use in U.S. Industries, New York, 1965, p. 9.

a) Chemical flocculation, and

b) Air flotation.

Chemical flocculation is intended as a preliminary treatment to increase the effectiveness of the air flotation process and to result in a high degree of clarification of separator effluent. The air flotation process is used because it is infinitely more effective than gravity separation or aeration at atmospheric pressure in removing emulsified oil, colloids and light suspended solids from refinery waste waters.[8] Other advantages of the process include:

a) The rapid rise rate of the suspended matter thus keeping the holdup time to a minimum.

b) The ability to handle shock loads of oil, flow and temperative changes.

c) The inherent advantage of preoxygenation of the waste water, thus oxidizing and removing most of the odorous components in the effluent.

It is beyond the scope of this report to go into the details of theory behind each phase involved, but only a general description involving all phases is presented.

Waste water leaving the separator enters the flocculation tank where coagulant and oxidizing agents are introduced and mixed with the waste water. The coagulant is to enhance flocculation, to coagulate

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(8) G.A. Rohlish, "Application of Air Flotation to Refinery Waste Water" J. Industrial and Engineering Chemistry. Vol. 46, Feb. 54, p. 307.

emulsified oils , and to agglomerate the fine particles before flotation, whereas the oxidizing agent is to remove odorous components from the waste water.

Effluent from the flocculation tank is mixed with a portion of the recycled clarified waste in the inlet compartment of the flotation tank. The recycled flow is pressurized, saturated with air, held pressurized in a 1-minute retention tank, then released to atmospheric pressure to the flotation tank. This reduction in pressure results in the release of microscopically air bubbles which attach themselves to suspended particles of oil, solids, and chemical flocs, and float to the surface forming a froth which is mechanically skimmed off.

Results of an extensive pilot-plant studies on oil separation from refinery wastes using different methods of pressurized flotation, shown in Fig. 4.4. indicated that, the recycle pressurization is most efficient in oil removal.[9] Hence, it is adopted here in handling the waste water from the flocculation tank. Other advantages of this method include:

a) With an effluent recycle, smaller pump is required contrasted with full flow pressurization and pumping costs are generally reduced.

b) The possibility of breaking of flocs and suspended matter, or of emulsification of free oil which may occur at the pressure release valve is eliminated, and

c) There is no raw water pumping, hence clogging the pressure release valve is avoided.

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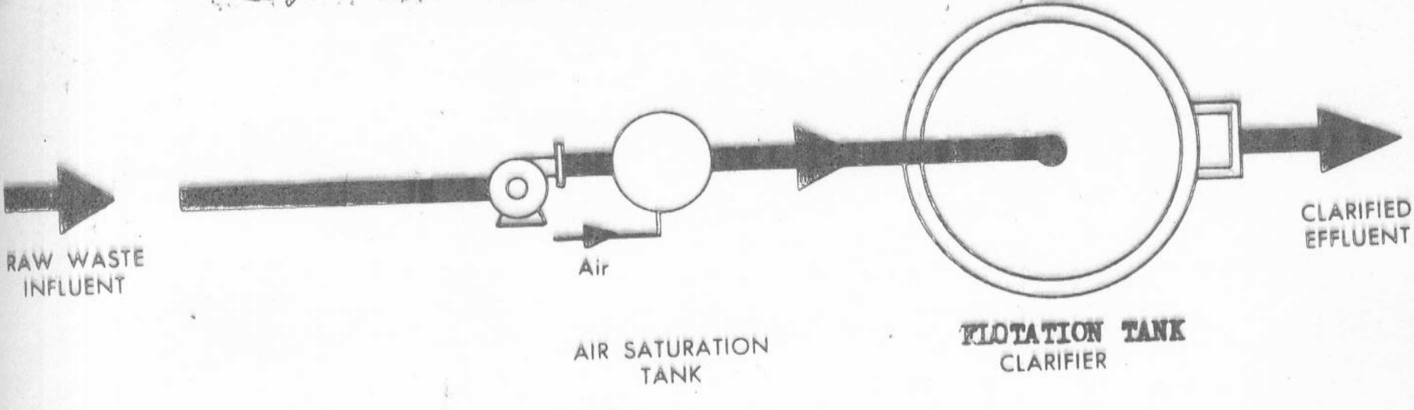
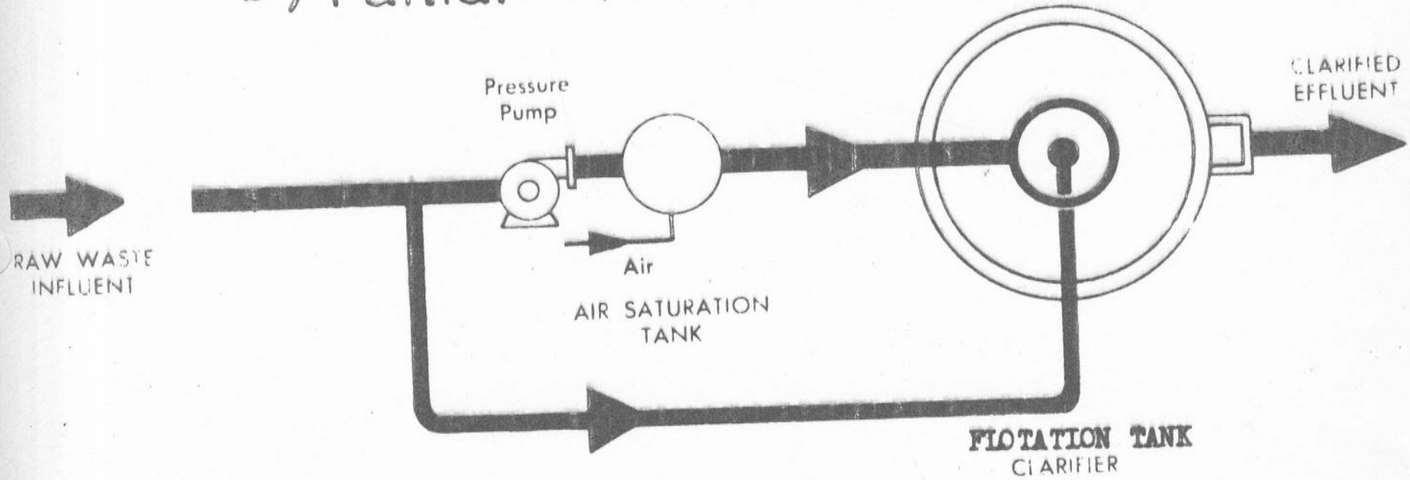
(9) Ibid., p. 306.

a) Full Flow Pressurization



b) Partial Pressurization



c) Recycle Pressurization

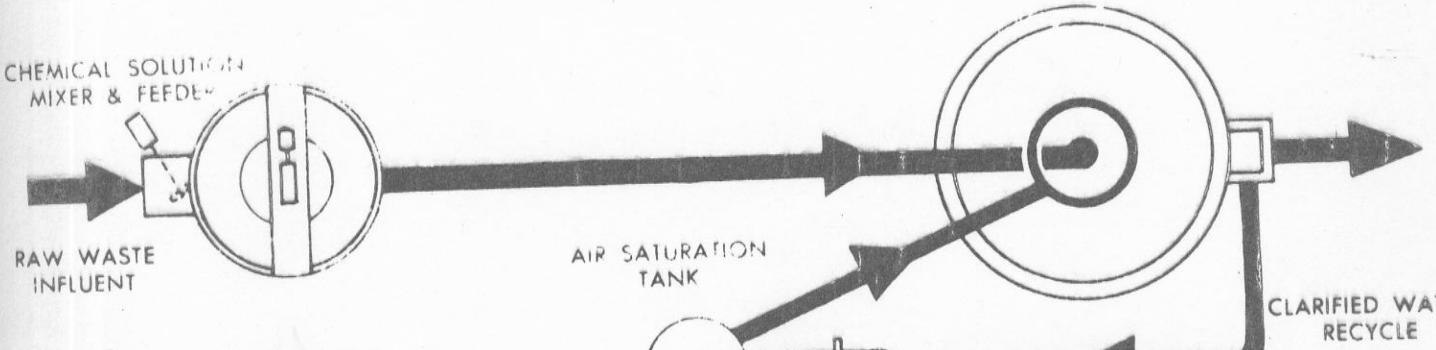
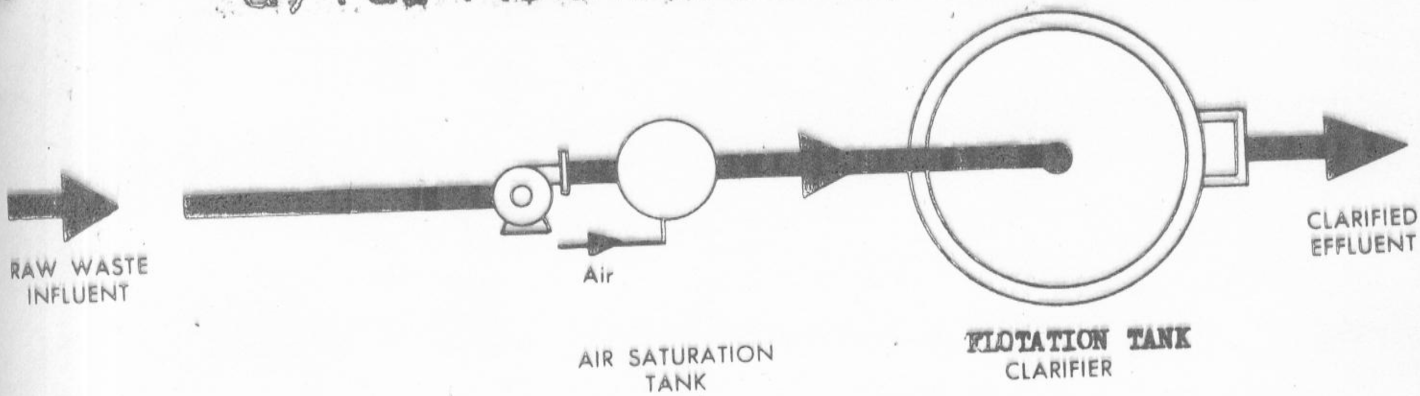
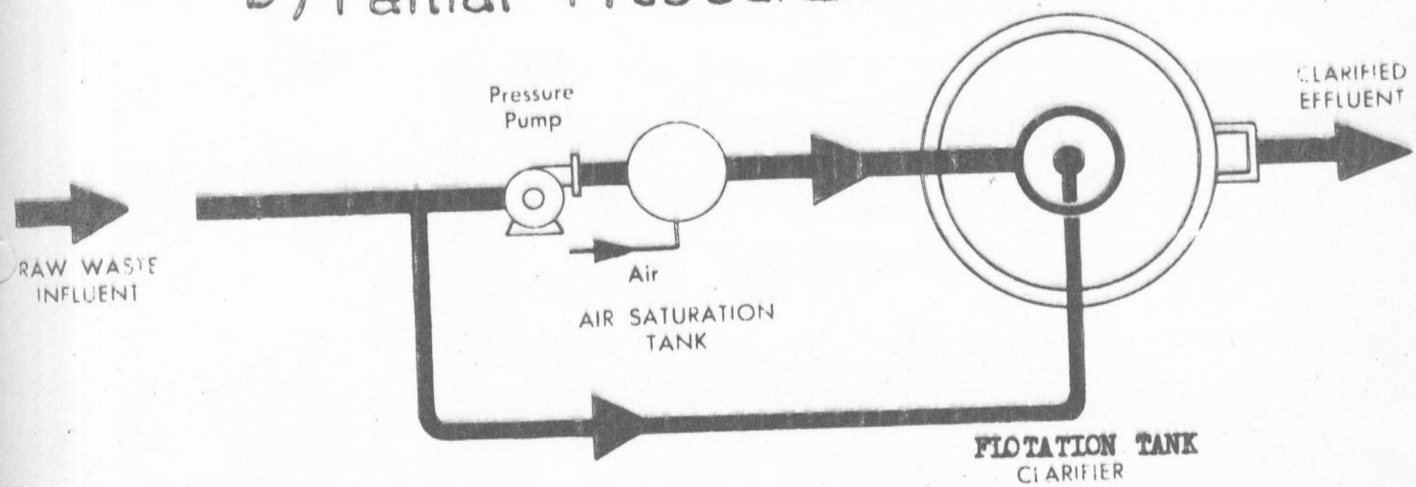


Fig. 4.4. Pressurization systems

a) Full Flow Pressurization



b) Partial Pressurization



c) Recycle Pressurization

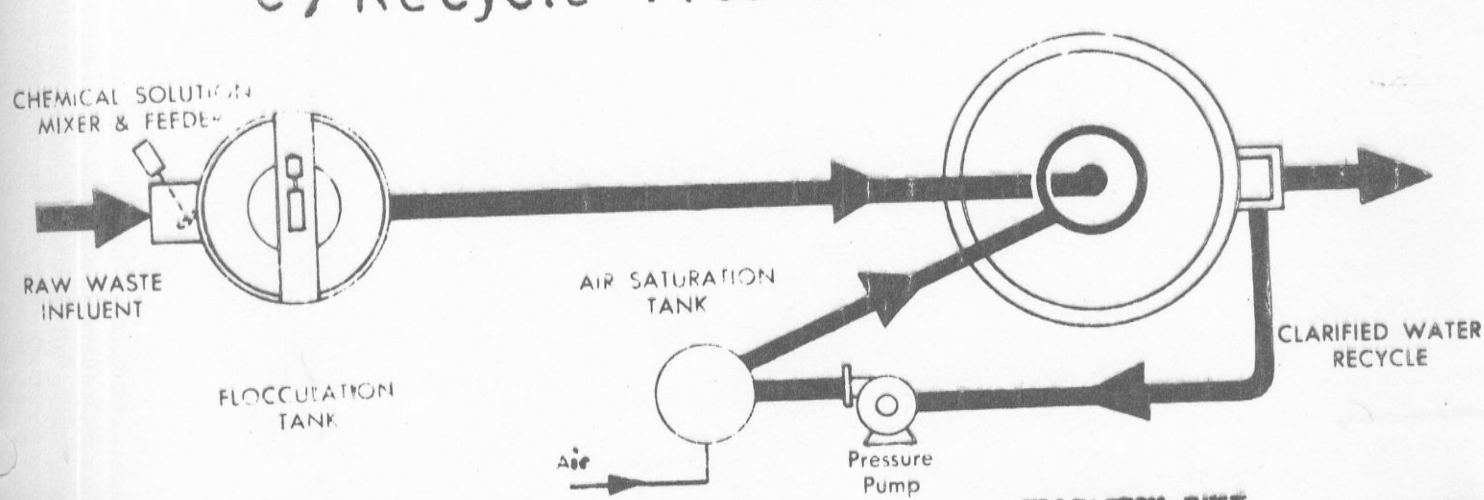


Fig. 4.4. Pressurization systems

Reclaimed water from the flotation tank ready for pumpage and usage in the refinery operations is collected in a storage tank with sufficient capacity to allow 4 hours storage.

4.3.3. Design of Reclamation Process Units.

a) Flocculation Tank.

The design of the tank is based on a maximum waste water flow of 1000 g.p.m., and a detention period of 5 minutes, a minimum flocculation time allowed. The volume of the tank required then becomes $\frac{1000 \times 5}{7.5} = 667$ cubic feet. The tank selected is a straightline flocculation tank measuring 6 feet wide by 23 feet long by 5 feet water depth.

While the most satisfactory flocculation is obtained by mechanical stirring puddles,[10] other advantages of mechanical flocculation include:

a) flexibility in speeds

b) constant intensity of agitation regardless of the variation in plant flow

c) little or no head loss in the plant flow, and

d) low power requirement.

The tank is equipped with a motor for the drive unit, and a rotating paddle which continuously stirs the liquid end mixes the entire tank content. The motor selected is a drive unit of

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(10) "Water Treatment Plant Design" Manual of Engineering Practice No. 19, ASCE. (1961), p. 30.

sufficient power to drive the paddle assembly and produce an average peripheral speed of 1.2 feet per second. Slower mixing may result in incomplete flow formation, or tendancy of the precipitate to settle in the flocculation tank, while too vigorous stirring may cause floc break up and subsequent poorly clarified water. In considering the following criteria:[(11)]

a) Flocs settle at velocities less than 0.3 ft./sec, and break up by velocities greater than 2.5 ft./sec.

b) The velocity imparted to the water in a flocculation tank is usually taken to be about $\frac{2}{3}$ of the peripheral speed of the agitation blade, and

c) The optimum velocity for coagulation is usually found to be from 0.5 to 2.0 ft./sec. for good results.

then the actual velocity in the design flocculation basin is found satisfactory. It varies from 1.3 to 1.6 ft./sec. as calculated below:

$$V \text{ max.} = \left(\frac{2}{3} \times 1.2\right) + \left(\frac{1000 \times 0.14}{60 \times 6 \times 5}\right) = 1.6 \text{ ft./sec.}$$

$$V \text{ min.} = \left(\frac{2}{3} \times 1.2\right) + \left(\frac{661 \times 0.14}{660 \times 6 \times 5}\right) = 1.3 \text{ ft./sec.}$$

One raw of paddle assembly 4 feet in diameter and 18 feet long is furnished for the tank and arranged as shown in Drawing No. 3.

Chemical coagulants and oxidizing agents are introduced at the inlet to the tank. The dosing of chemicals is regulated by an electro-chemical variable rate proportimating feeder. Jar tests

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(11) Ibid., pp. 28-34.

performed on composite samples of process waste water procured from the Sidon Refinery indicated that the optimal dose of alum is 20 ppm in the pH range of 6.9 - 7.1 . The optimum dose of potassium permenganate was found to be 6 ppm as determined by jar tests on the basis of its effect on eliminating taste and odor components.

b) Flotation System Components

Drawing No. 3, shows the essential elements of the flotation system utilizing the recycle pressurization and depressurization sequence which consists of the pressurizing pump, air injection facilities, the pressure tank, the back pressure regulating device, and the flotation tank.

Pressurizing Pump.

The pressurizing pump is selected to operate 24 hours a day, and to discharge a continuous and constant supply of recycle effluent of 400 gallons per minute from flotation tank outlet into the pressure tank maintained at an elevated pressure of 30 psig. The recycled pressurized effluent amounts to 40% of the maximum raw waste flow.

The pump is a 6"/6" vertical end suction, single stage centrifugal pump, close coupled with an electric motor. The pump is to operate under a total head of feet, calculated as follows:

a) Static head

Total change in elevation of the liquid from suction level to discharge level (Drawing No. 3) = 8.0 ft.

Total pressure difference of suction and discharge tank, 30 psig. = 69.3 ft.

Total static head = 77.3 ft.

b) Velocity head

The velocity head at the end of the discharge pipe, 6-in. diameter:

$$\frac{V^2}{2g} = \left[\frac{\frac{400 \times 0.14}{60}}{\frac{\pi}{4} \times \left(\frac{6}{12}\right)^2} \right]^2 \times \frac{1}{64.4} = 0.40 \text{ ft.}$$

c) Frictional losses

The frictional losses are calculated for a flow of 400 g.p.m. The losses due to the fittings are obtained in equivalent length of straight pipe by nomograph of Fig. 4.5. and added to the straight length of the cast iron pressure pipe line of American Standard, class 250 lbs, with a working pressure of 250 psi.

Length of pipe	=	35 feet
Entrance loss 6" pipe	=	8 feet
Bend losses 4 x 10	=	40 feet
Gate valve 1 x 4	=	4 feet
Check valve 1 x 40	=	40 feet
Outlet losses 6" pipe	=	15 feet
Total Length	=	142 feet

Figure 4.5.

RESISTANCE OF VALVES AND FITTINGS TO FLOW OF FLUIDS

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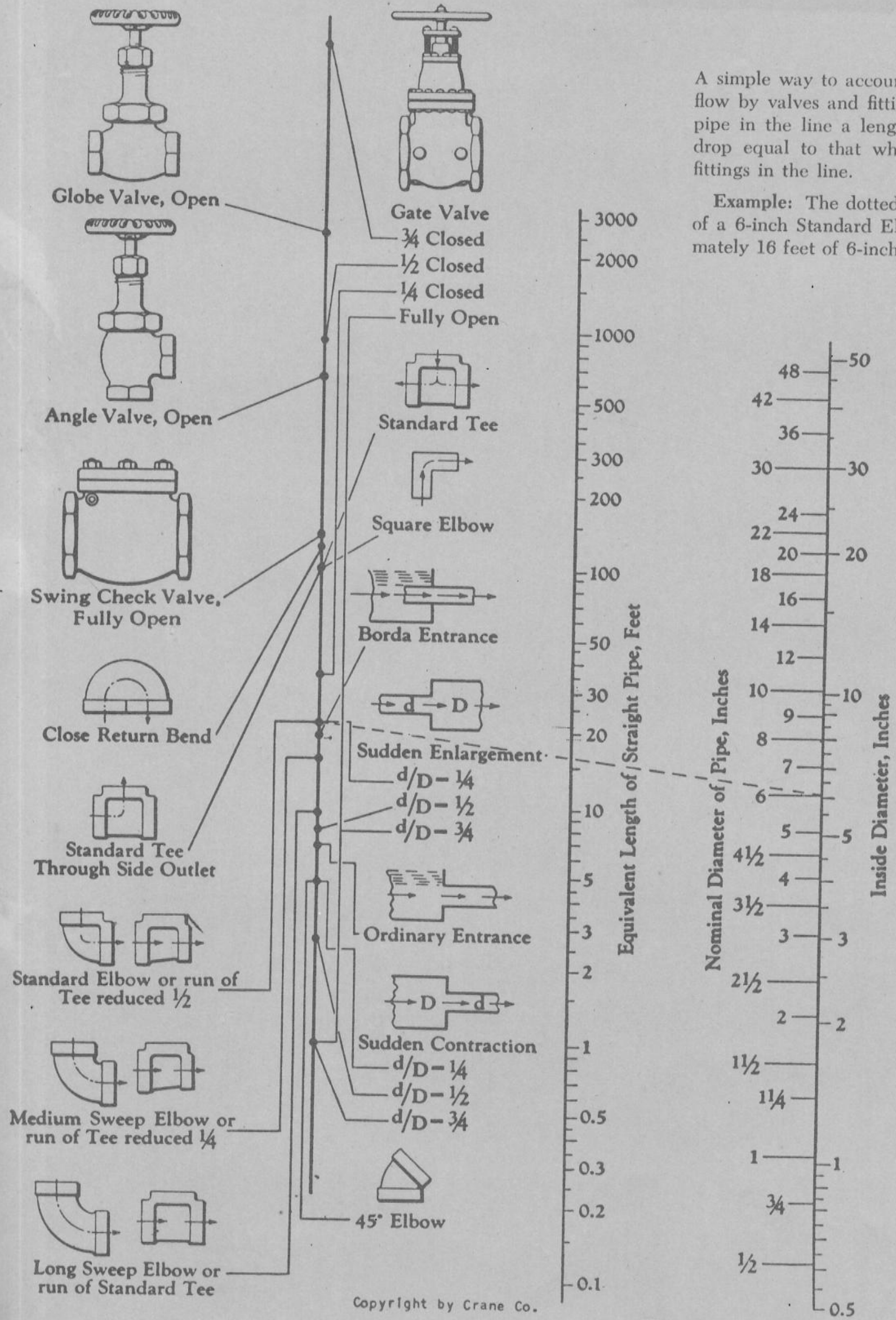
A simple way to account for the resistance offered to flow by valves and fittings is to add to the length of pipe in the line a length which will give a pressure drop equal to that which occurs in the valves and fittings in the line.

Example: The dotted line shows that the resistance of a 6-inch Standard Elbow is equivalent to approximately 16 feet of 6-inch Standard Steel Pipe.

Note: For sudden enlargements or sudden contractions, use the smaller diameter on the nominal pipe size scale.



Therefore, loss of head for a discharge of 400 gpm, and pipe 6" diameter, from nomograph of Fig. 4.6.

$$H_f = 142 \times \frac{18}{1000} \times 1.5$$

$$= 3.8 \text{ ft.}$$

Hence, the total head which the pump has to develop, and the pressure pipe line has to maintain,

$$H = 81.5 \text{ feet or } 35 \text{ psi.}$$

It remains to the manufactures to recommend a type and size of the pump, with its speed that will give the best efficiency.

To check for the water hammer in the pressure pipe line[6]

$$h = \frac{Vo\ C}{g}$$

where,

Vo = initial velocity $\frac{Q}{A}$ = 5.1 ft/ree

C = speed of pressure wave

For water in a pipe

$$C = \frac{4720}{1 + \frac{KD}{RT}}$$

where

K == Bulk Modulus 3×10^5

R = Modulus of Elasticity 15×10^6

T = Thickness of pipe 0.44 in.

D = Diameter of pipe 6 in.

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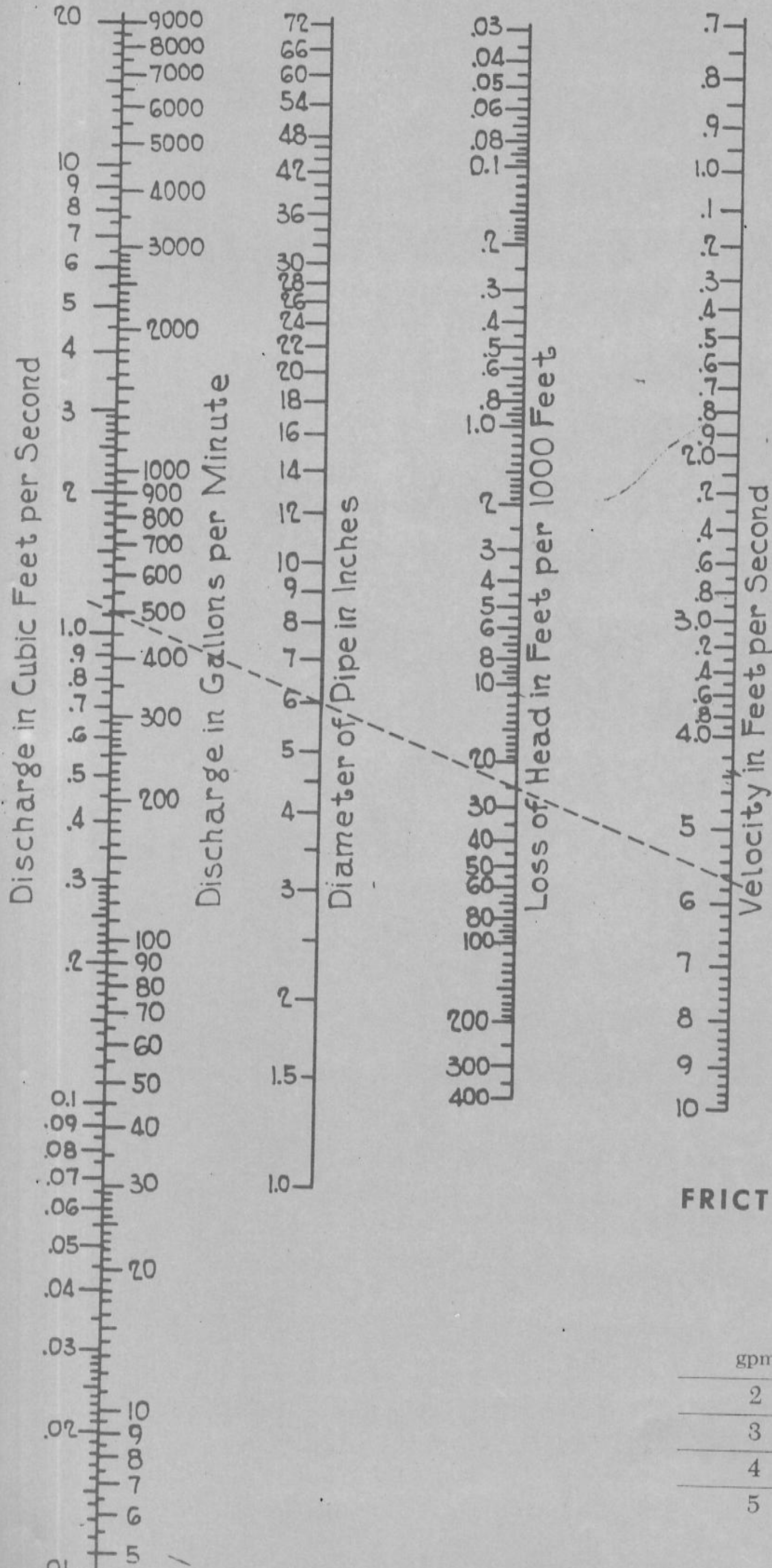
(6) V.S. Streets, Fluid Mechanics, 3rd. edition, New York: McGraw Hill Book Co., Inc., 1962, p. 466.

Figure 4.6.

PIPE FRICTION LOSS CHART

DIAGRAM FOR CALCULATING PIPE SIZES, DISCHARGE VELOCITIES AND LOSS OF HEAD IN STANDARD STEEL PIPE

(For Cast Iron and Concrete Pipes See Note at Right)



Lay a straightedge on scales at the points for any two known quantities and the unknown quantities will lie at intersection of the straightedge with the other scales.

Example: To discharge 500 gals. per minute through 6″ pipe, following dotted line would show loss of head in a thousand feet of approximately 25 feet head and velocity of 5.7 feet per second.

Note: Loss of head in Cast Iron Pipe = loss of head in steel pipe multiplied by 1.5.

Loss of head in Concrete Pipe = loss of head in steel pipe multiplied by 2.

When pipe is somewhat rough add 10% to loss of head; when very rough add 25%.

FRICTION OF WATER IN SMALL PIPES

Loss of Head in Feet Due to Friction Per 100 Feet of Smooth Straight Pipe

gpm	½ Inch Pipe	¾ Inch Pipe	1 Inch Pipe
2	7.57	1.93	0.595
3	16.0	4.08	1.26
4	27.3	6.94	2.14
5	41.2	10.5	3.24

$$C = \frac{4720}{1 + \dfrac{3 \times 10^5 \times 6}{15 \times 10^6 \times 0.44}}$$

$$= 4070$$

$$h = \frac{4070 \times 4.7}{32.2}$$

$$= 490 \text{ ft.}$$

Total water hammer = 490 + 81.5

= 571.5 ft.

= 246 psi

and the allowable working pressure = 250 psi

Pressure Tank

The pressure tank is of mild steel fusion vertical pressure vessel, designed to maintain as nearly constant a discharge head on the pressurizing pump as possible, and to provide a constant pressurized and air saturated supply of water to the flotation tank. The size of the tank is dependent upon the quantity of water which must be pressurized and the amount of dissolved air required. The tank has 1-minute detention capacity of 400 gpm recycle effluent flow.

Water is supplied and drawn off from the pressure tank at the same rate of 400 gpm. The tank is maintained under 30 psig pressure at all times to insure increased solubility of air for effective flotation when the pressure is released.

The tank is 3.5 feet in diameter and 6.75 feet side sheet. It is provided with the necessary accessories of floatswitches, pressure gauges, air bleed valve, excess air outlet, selonoid operational drain, water level gauge, and all the other necessary fittings to insure complete safety and releability in operation. A 6-in. diameter piping connecting the pump to the pressure tank is supplied, whereas the piping between the air compressor and the pressure tank is 2-in. in diameter.

Air Compressor

The air handling ability of centrifugal pumps is limited to a range in the order of 2 to 4 per cent by volume. In flotation use, under pressure of 20 to 50 psig, to entrain the amount of air required for saturating the flow, it is necessary to dissolve about 5 to 8 per cent of free air by volume. Therefore, it is apparent that the pump cannot be used successfully in impressing air to the system. A compressor is used for the purpose.

In general, the greater the amount of air dissoled, the greater the air evolved and the greater the bouyant effect of the floatable solids. In other words, the quantity of air required depends upon the amount of solids or other materials to be floated. Information on the quantity of solids to be removed can best be obtained from:

a) Pilot plant studies

b) Laboratory data

c) Experience gained from similar installations.

In the absence of such information, the quantity of air required to saturate the flow is estimated based on solubility of air in water. Knowing:

a) Solubility of air in water is 1.87 per cent by volume at 68^{o}F. and 1 atmosphere.

b) The amount of air going into solution increases with the pressure to which the liquid is subjected, according to Henry's Law.

$$Ca = HP_t \tag{5.12.}$$

where

Ca = Quantity of air dissolved

P_t = Pressure, in psig.

H = A function of temperature

= 6.07 at 68°F

= 7.71 at 85°F

Therefore, at 68°F., and 1 atmosphere, the volume of air required to saturate 400 gpm flow of recycle effluent equals to:

$$Ca_1 = 1.87 \times \frac{400}{100} \times 0.14$$

$$= 1.05 \text{ cubic feet/min.}$$

At the design temperature of 85°F., and pressure of 30 psig, the quantity of air required to saturate the flow, equals to:

$$Ca_2 = 1.05 \times \frac{7.71}{6.07} \times \frac{30}{14.7}$$

$$= 2.7 \text{ cubic feet/min.}$$

Therefore, a compression **having a capacity of 2.7** cubic feet/min. at 30 psig is required.

It remains to the manufactures to recommend a type and size of the compressor, with its speed that will give an air supply of 2.7 ft^3/min. at a net pressure of 30 psig.

Flotation Tank

For reasons of economy, the flotation tank selected is a rectangular chamber measuring 30 feet long, 10 feet wide, and has a water depth of 6 feet. The size of the tank is based on the following design criteria:[7]

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(7)

McCabe, B.J., and Eckenfelder, W.W., Biological Treatment of Sewage and Industrial Wastes. New York: Reinhold Publishing Corporation, p. 237.

a) Surface overflow rates range from 1.0 to 4.0 gallons per minute per square feet.

b) Minimum effective depth of 6 feet of water is essential.

The detention time is not a design criteria. It usually, varies from 10 to 40 minutes.

With a maximum flow of 1000 gpm plus a 400 gpm of pressurized effluent making a total flow to the unit of 1400 gpm. This represents an overflow rate in the flotation chamber of 4 gallons per minute per square feet. With a water depth of 6 feet, the holding time in the flotation tank becomes 11 minutes which is satisfactory.

The pressurized water, having been saturated with air, passes the pressure relief valve located near the distribution header, and enters at the bottom of the mixing zone of the flotation tank. The recycle distribution slotted header is tapered to insure blending of recycle flow with raw wastes across full width of the tank. In the mixing zone, the pressurized recycle stream gives up its dissolved air in the form of minute air bubbles and accomplishes effective flotation of the raw waste.

The tank is equipped with a slotted inlet baffle to insure proper flow distribution across width and depth of basin, and a skimmer to skim the float in the mixing zone. In addition, a mechanical flight scraper, a collection hopper, and draw-off piping are provided for collecting the non-floatable settled solids, and removal intermettantly to the sludge basin.

The clarified water is taken off through the effluent box provided with an entrance weir to control liquid level in the flotation tank. The box is designed to provide a 400 gallons storage capacity for the recycle system while extra flow passes to the final storage tank.

Final Storage Tank

After flotation, 400 gpm of reclaimed water is recirculated, and the remainder is collected in a storage tank having a capacity of approximately 170,000 gallons, holding an average flow of 700 gpm for 4 hours.

With an effective depth of 10 feet, then:

$$\text{Area of the tank required} = \frac{170000 \times 0.14}{10}$$

$$= 1{,}380 \text{ square feet}$$

A size of 40 x 35 feet is recommended.

An emergency by-pass is provided in the tank so that under extreme conditions, when the tank is full, excess flows are allowed to drain to the river.

A 700 gpm recirculation centrifugal pump 8"/8" vertical and suction, is provided to pump the reclaimed water from the tank to the water distribution system which is at a higher level. Pumping is done in the direct pumping system over a 24 hours a day basis. Under such conditions, the least factor is the shortage of electricity, that will intercept the supply of water. But, because the electrical supply is locally provided and is assumed to be continuously available no standby pump is provided. Only one pump with 700 gpm capacity will work, and stop and start automatically as the pressure in the mains drop, below 40 psi. The total head, against which the pump has to work is accounted as follows:

a) Static head

Total change in elevation of liquid from suction

level to highest discharge
level (approximated) 50.0 ft.

Total pressure difference of suction and discharge ends, 40 psig	92.4 ft
Total static pressure	142.4 ft

b) Velocity head

$$\frac{V^2}{2g} = \left[\frac{\frac{700 \times 0.14}{60}}{\frac{\pi}{4} \times \left(\frac{8}{12}\right)^2} \right]^2 \times \frac{1}{2 \times 32.2} = 0.3 \text{ ft.}$$

c) Friction losses

An approximate length of the water distribution network is estimated. Additional equivalent length for fittings is added to the straight length of the 8" steel pipe. Total length (approximated) 3000 ft.

Loss of head for a discharge of 700 gpm, and a steel pipe 8 inch in diameter from nomograph of Fig. 4.6.

$$H_f = 3000 \times \frac{11}{1000} = 33.0 \text{ ft.}$$

Hence, the total head which the pump has to develop and the pressure line has to maintain is:

$$H = 175.7 \text{ ft. say } 176 \text{ feet.}$$

It is left to the manufactures to recommend a type and size of the pump, with its speed that will give the best efficiency.

The foregoing facilities designed for such a treatment are expected to removed more than 91% of the oil, and reduce solids and oxygen demand to more than 75%. In the construction, reinforced concrete is recommended to give satisfactory service, smooth surfaces, and avoid leakages.

4.3.4. Cost of Reclamation

The preparation of detailed cost estimate is beyond the scope of this report. It is, therefore, proposed to approximate the quantities of worl needed and costs involved in order to give an idea of the cost of reclaiming water from process waste water. The cost data include all capital, operation, and maintenance charges for all works required in addition to those already in use by the refinery for the routine treatment processes.

For the purpose of the work approximate rates have been adopted for the different items included. In the cost of analysis the following considerations were taken into account:

a) An over-all 20 year life span because of the possibility of technological obsolescence.

b) Maintenance and supervision costs at 3 per cent over the capital cost.

c) Neglect of electricity charges because the supply of electricity is by the refinery's private power plant.

The estimate of quantity and costs is as shown in Table 4.1.

Table 4.1. Estimated Cost of Reclamation of Process Waste Water - 1 MGD

A. Capital Cost Item	Cost (L.L.)
Construction of flocculation tank as per drawing including the paddle assembly, driving motor, and all necessary accesories.	15,000
Supply and installation of electro-chemical feeders as per specifications, complete job, 2 at L.L. 1000.	2,000

Capital Cost (Cont'd)

Item	Cost (L.L.)
Supply and installation of pumps close coupled with motors (Complete job) P_1 - 400 gpm at L.L. 8,000; P_2 - 700 gpm at L.L.10,000	18,000
Supply and construction of pressure pipe (complete job) 6 in. diameter 40 feet at L.L. 12; 8 in. diameter 40 feet at L.L. 15	1,080
Supply and installation of pressure tank as per drawing, complete job, with all fittings and accessories.	1,500
Supply and installation of air compressor as specified with the driving motor close coupled.	2,000
Construction of flotation tank as per drawing including all mechanical equipment(complete job).	10,000
Construction of final storage tank as per drawing. Complete job.	10,000
Supply and installation of the following fittings	
2 - 8" check valves at L.L. 400	800
4 - 8" gate valve at L.L. 150	600
5 - 8" 900 bends at L.L. 30	150
Engineering and contigencies	870
Total	62,000

B. Annual Operation Cost

Maintenance and supervision, 3 %	1,860
Chemicals	1,000
Amortization of construction costs, 20 years	3,100
Interest, 4%	2,480
Utilities - including power for pumping, labor for operation	—
Total	7,440

Hence, the operating cost of reclaimed water per 1,000 gallons amounts to L.L. 0.02

The estimated average over-all waste water reclamation cost which includes allowances for treatment, pumping, and distribution to the existing network of pipe line, is much less than the cost of converting saline water to fresh in the area. This conclusion is verified by the data presented in Table 4.2. The table assembles the various cost data described for producing water by reclaiming sewage and by converting salt water to fresh in U.S. The Table also includes, for purpose of comparison, data on estimated costs of certain natural fresh waters already in use in certain water-shortage areas of the States. The data demonstrates conclusively that reclaimed water is economically competitive in these areas, costing either less or no more than imported natural supplies, and very much less than distilled sea water.(8)

4.4. Hydraulics Through Plant

The flow of waste water, through the separator and reclamation plant requires sufficient head to overcome the hydraulic losses between and through the various structures of the treatment processes.

The total head available, as well as the hydraulic losses vary with the rate of flow, and because the hydraulic design is concerned with the hydraulic capacity, then the hydraulic losses are based on the maximum rate of flow. On the other hand, to determine the proper elevations for various plant elements the hydraulic gradient through the plant is computed for maximum and minimum rates of flow.

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(8) "Present Economic and Technical Status of Water Reclamation from Sewage and Industrial Wastes", Sanitary Engineering Research Project, University of California, Technical Bulletin No. 4, March 1951, p. 18.

TABLE 4.2.

WHOLESALE COST OF FRESH AND RECLAIMED WATER

TYPE OF WATER SUPPLY	SOURCE OF WATER	COST PER ACRE FOOT[1]	REFERENCE NUMBER	REFERENCE DATE
	METROPOLITAN WATER DISTRICT OF SOUTHERN CALIFORNIA[3]	$20	31	1949
	Production, exclusive of interest & bond redemption[4]	12	31	1949
	Interest & bond redemption	8	31	1949
FRESH	LOS ANGELES (Aqueduct Water)[5]	$19	32	1950
	Cost exclusive of interest on investment in lands	15	32	1950
	Interest on investment in lands	4	32	1950
	RAYMOND BASIN EXCHANGE WATER[6]			
	Average cost for 11 parties in Western Unit	$29	33	1946-47
	City of Pasadena	34	33	1946-47
WATER	Average cost for 10 parties; Pasadena not included	20	33	1946-47
	EAST BAY MUNICIPAL UTILITY DISTRICT (Mokelumne River Water)[7]	$40	34	1950
	SAN FRANCISCO CITY AND COUNTY[8]			
	Large individual consumers	$59	35	1951
	South peninsula cities and companies buying water for resale	70	35	1951
SUPPLIES[2]	CALIFORNIA CENTRAL VALLEY PROJECT[9]			
	City of Richmond	$17	36	1950
	City of Vallejo	14	36	1950
	DOMESTIC WATER - RETAIL[8]			
	Range of U.S. cities	$30-80	37	1945
	DISTILLATION			
SEA	Vapor compression	$400-500	31	1949
	Vapor compression	67-100	38	1949
WATER	Vapor compression	208	39	1949
	Multiple-effect evaporator, 5 effects	160	40	1948
RECLAMATION[10]	ANION & CATION DEMINERALIZER (chemicals only)	8000	31	1949
	ELECTROLYTIC PROCESS (power only)	293	31	1949
	FREEZING	400	31	1949
	LOS ANGELES COUNTY			
WASTE	New reclamation plants[11]	$16	10	1949
	Existing, but inactive, reclamation plant (activated sludge)[12]	9	10	1949
WATER	SANTA CLARA WATER CONSERVATION DISTRICT[13]	16-19	19	1949
RECLAMATION	ORANGE COUNTY[14]	20	12	1947

1. Cost figures have been taken to nearest dollar. For sea water and waste water reclamation, costs have been estimated by various engineering groups (see reference numbers).

2. Most of the fresh-water supplies are imported, although some well-water supply costs are included in the Raymond Basin Exchange Water figures.

3. Cost of softening and filtering the supply for domestic use, which is approximately $10.00 per acre foot, is not included in the $20.00 figure.

4. It is estimated that the production cost, exclusive of interest and bond redemption, will ultimately decrease from $12.00 to $8.00 per acre foot.

5. The costs are related to the rated capacity of the Aqueduct, 319,000 acre feet per year. They are based on interest at 4½% and on an expected life of 67 years for the principal aqueduct structures.

6. "Undue Costs" amounting to approximately $1.32 per acre foot have not been included in the average figures.

7. The cost is a weighted average based on quantity of water delivered and total cost for the years: 1930-31, 1934-35, 1939-40 and 1944-45.

8. Costs include distribution to the consumer.

9. Estimated costs for raw water at canal site.

10. Costs for reclamation of sea water have been taken from Table 9, where they are also expressed in cost per 1,000 gallons and cost per million gallons.

11. Cost, which is estimated average over 50-year period, is based on activated sludge plant of 10 MGD capacity, 50-year serial bonds, 4% interest, and assuming operation 95% of time. Cost is typical for the many other alternates which are considered in the report. The breakdown of the average cost of $16.00 per acre foot is given in Table 8.

12. Cost, which is estimated average over 40-year period, is based on existing activated sludge plant of 8 MGD capacity, 50-year serial bonds, and 4% interest.

13. Cost, which is estimated average over 40-year period, is based on 40-year serial bonds and 3% interest.

14. Cost, which is estimated average over 40-year period, is based on activated sludge plant of 51 MGD capacity, 40-year serial bonds, and 2% interest. It includes pumping plants, force mains, and pipes necessary for distribution of the reclaimed waters on agricultural lands.

+ The Table is depicted from the Technical Bulletin No. 4, issued by University of California, March 1961.

Based on future rates of flow

Q min. = 661 g.p.m.

Q av. = 700 g.p.m.

Q max. = 1,000 g.p.m.

the overall head losses through the plant is estimated as follows:

a) Head losses from Separator inlet to Flocculation tank inlet.

Starting in elevation with the hydraulic gradient at the inlet of the sewer to the separator the hydraulic losses at the higher rates of flow are calculated to determine the hydraulic gradients at the inlet of the sewers to the flocculation tank, flotation tank, and storage tank.

Using a cast iron pipe with n = 0.013, and refering to Figures 4.5., 4.6., and 4.7., the hydraulic elements of the inlet pipe to the separator are determined and recorded as shown in Table 4.3.

Table 4.3. Hydraulic Elements of Inlet Pipe

Hydraulic Elements		Full Flow (max.)	Partial Flow (min.)
Flow,	Q, g.p.m.	1,000	661
Pipe diameter,	D, inches	15	15
Velocity,	V, ft/sec.	1.8	1.9+
Water Depth,	d, inches	15	8.7
Water Level,	El., cms.++	402	386

\+ Under conditions where n, and h_f are constant with changes in water depth in the sewer.

++ Elevation are in metric system relative to the main sea level. Invert elevation of inlet sewer to the separator is 364 cms. above the datum.

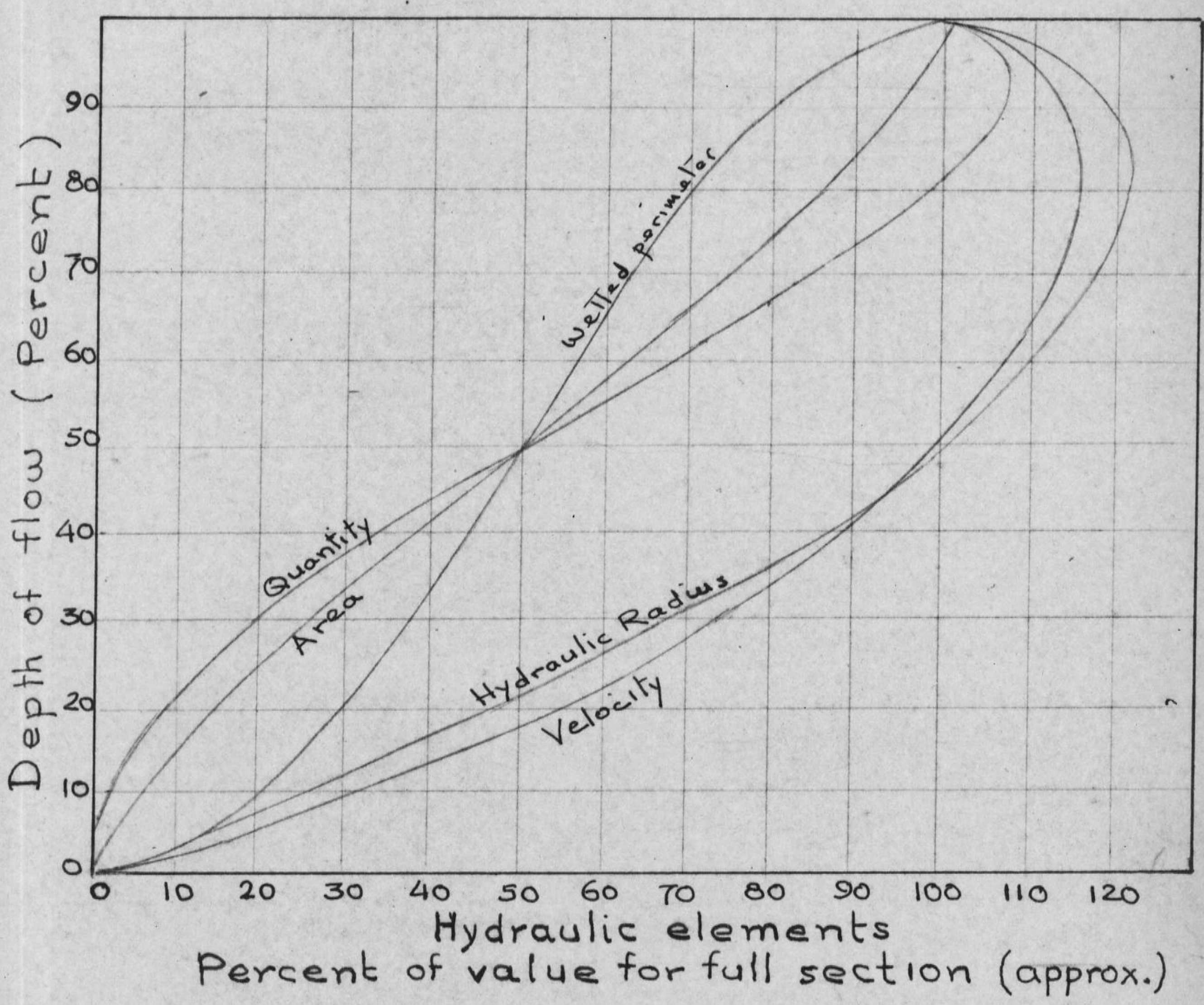

Figure 4.7. Values of hydraulic elements of circular section for various depths of flow

Hydraulic losses, including friction losses and velocity losses expressed in equivalent lengths of pipe, 15 in. in diameter, are determined as follows:

From Figure 4.5.,

Entrance losses	(enlargement)	=	40 feet.
Outlet losses	(contraction)	=	10 feet.
Gate Valve 15"	(Outlet pipe)	=	10 feet.
Standard Tee 15"	(by-pass)	=	80 feet.
Length of pipe 15" diameter.		=	5 feet.
	Total Length		170 feet.

From Figure 4.6.,

$$\text{Head loss} = 170 \times \frac{1.5}{1000}$$

$$= 0.255 \text{ feet.}$$

Allowing for outlet weir losses, calculated to be 0.13 feet (Section 4.2.4.) and accounting for free fall below weir of 0.2 feet, and neglecting the relatively small losses, then the total head loss

$$H_f = 0.255 + 0.13 + 0.20$$

$$= 0.585 \text{ feet.}$$

$$= 18 \text{ cm.}$$

To provide a factor of safety, the hydraulic gradient at the inlet of the sewer to the flocculation tank is set 20 cms. below the low water level in the inlet sewer to the separator - i.e. at elevation 366 cms. above datum. The invert elevation of the 15-in inlet sewer to the flocculation tank becomes 366 - 22 = 344 cms. above datum.

b) Head losses from Flocculation tank inlet to Flotation tank inlet.

Neglecting the relatively small losses in the tank, the losses are mainly entrance losses (enlargement) and is calculated to be:

$$h_f = 40 \times \frac{1.5}{1000}$$

$$= 0.06 \text{ feet.}$$

$$= 2 \text{ cms.}$$

Again, to provide a factor of safety, the hydraulic gradient at the inlet of the channel to the flotation tank is set 4 cms. below the low water level is the inlet sewer to the flocculation tank, i.e. at elevation 360 cms. above datum. The bottom elevation of the 6 feet wide, channel to the flotation tank is set at 350 cms. above datum to provide a velocity varying from 1.1 - 1.5 ft./sec. which is satisfactory to prevent settling or breaking the chemical flocs.

c) Head losses from Flotation tank to Final Storage tank.

Head losses in equivalent length of pipe, include:

Outlet losses	(contraction)	=	25 feet.
90° Bend - 15 inches.		=	50 feet.
Gate Valve 15 inches.		=	10 feet.
Inlet Losses	(enlargement)	=	40 feet.
Length of pipe 15 inche		=	10 feet.
	Total Length		135 feet.

From Figure 4.5., head loss

$$h_f = 135 \times \frac{1.5}{1000}$$

$$= 0.21 \text{ feet.}$$

Allowing for outlet weir loss, calculated by equation 4.4., for maximum flow 1,400 g.p.m.

$$H = \left(\frac{1,400 \times 0.14}{60 \times 3.33 \times 8} \right)^{2/3}$$

$$= 0.25$$

Accounting for free fall losses below weir, as in (a), then the total head loss

$$H_f = 0.21 + 0.25 + 0.20$$

$$= 0.66 \text{ feet.}$$

$$= 20 \text{ cms.}$$

Therefore, the hydraulic gradient at the inlet of the sewer to the storage tank is at elevation 330 cms. above datum.

Finally, the hydraulic profile is plotted Figure 4.8., showing the difference is elevation of the hydraulic gradients at maximum and minimum flow stating from the inlet of the sewer to the separator and ending to the inlet of the sewer to the storage tank.

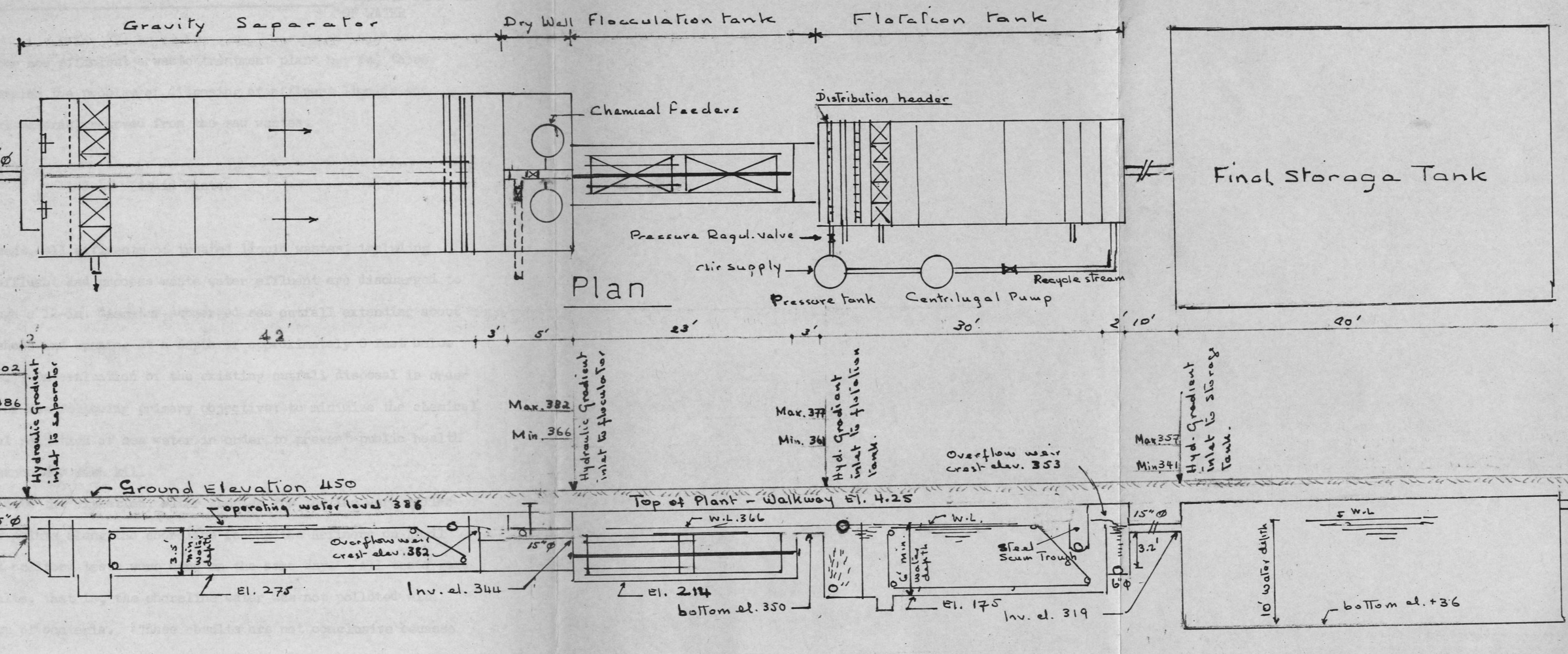

Figure 4.8. Hydraulic profile through plant

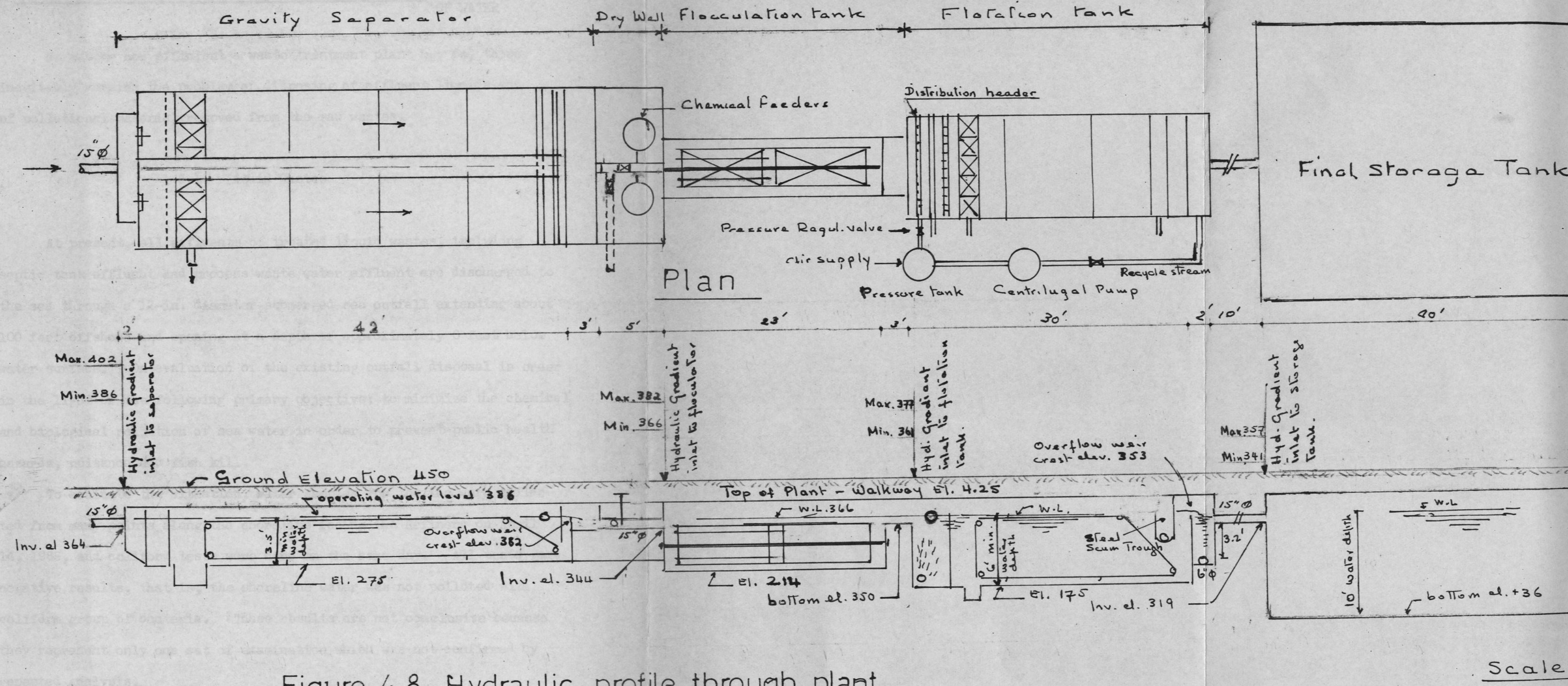

Figure 4.8. Hydraulic profile through plant

No matter how efficient a waste treatment plant may be, there inevitably remains the problem of disposing of effluent liquids and of pollutional material removed from the raw wastes.

5.1. Liquid Wastes

At present, all effluents of treated liquid wastes, including septic tank effluent and process waste water effluent are discharged to the sea through a 12-in. diameter submerged sea outfall extending about 100 feet offshore and opening at a depth of approximately 6 feet below water surface. On evaluation of the existing outfall disposal is order in the light of the following primary objective: to minimize the chemical and biological pollution of sea water in order to prevent public health hazards, nuisance and fish kill.

To evaluate the situation, water samples for testing were collected from many points along the shoreline facing the Refinery on April 14, 1965, and coliform tests were done on the same day. All tests gave negative results, that is, the shoreline water was not polluted with coliform group of bacteria. These results are not conclusive because they represent only one set of examination which was not confirmed by repeated analysis.

The disposal of the partially treated liquid wastes offshore into the sea, necissatates an adequate dilution and dispersion of effluent to avoid objectionable and hazardous conditions. The determination of the adequateness or the rate of dilution necessary, is a problem that has been given much attention by Sanitary Engineers and others, and the criteria presented here is the outcome of their intensive laboratory experiments and research work.

5.1.1. Rates of Dilution

From a physical and chemical standpoint, the rate of dilution necessary to meet the disposal objectives is that necessary to maintain the minimum permissible dissolved oxygen content of 4 ppm in the diluted effluent. This standard was arbitrarily set by T.V.A. in 1945, to protect wildlife resources and recreationed activities.(1)

A rough approximation of the dilution rate can be arrived at by considering:

a) D.O. in sea water,

b) B.O.D. of liquid effluent,

c) B.O.D. of sea water, and

d) Quantity of flow of liquid effluent.

In evaluating these factors the two situations that would be confronted are:

a) The present situation whereby all the liquid effluents are combined first in the outfall sewer, then discharged to the sea, and

b) The future situation whereby only the septic tank effluent is to be discharged into the sea, while the process waste water effluent is reclaimed and returned to the refinery operations.

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(1) E.W. Stell, Water Supply and Sewerage (New York; McGraw Hill Book Co., Inc., 1953), p. 470.

Obviously, the second situation with reduced percentage of more highly concentrated wastes for disposal is more critical and hence thorough consideration is warranted.

Characteristics and analysis of septic tank effluent and sea water samples indicated the following average values:

a) Septic tank effluent:

5-day B.O.D. 200 parts per million

Dissolved Oxygen 0 -"-

Maximum predicted daily flow (Figures 3.1 and 3.2) = $\frac{7.5 \times 305}{270}$

= 8.3 g.p.m.

Minimum predicted daily flow (Figures 3.1 and 3.2) = $\frac{2.25 \times 305}{270}$

= 2.5 g.p.m.

b) Sea Water:

5-day B.O.D. 0 ppm

Dissolved Oxygen 6.8 ppm at 85°F.

Therefore, if X is the required flow of diluting water, the equation balancing oxygen demand and available oxygen at maximum flow rates will be

$$8.3 \times 200 = X\,(6.8 - 4.0)$$

then, $X = 640$

This provides a dilution factor of $\frac{640}{8.3} = 77$

From the bacteriological standpoint, the rate of dilution necessary to meet the disposal objectives is to maintain a maximum permissable coliform concentration at shoreline water not to exceed

10 E. coli per milliliter. This standard was arbitrarily based many years ago on experience in California.[2]

To achieve this bacterial concentration Rawn and Palmer suggested a dilution factor of 225 at the periphery of the sewage field.

This factor is, therefore, the governing one and has to be checked.

5.1.2. Mixing and Dilution

Having laid down the minimum permissable dilution factor, there remains the question of evaluating the existing outfall and checking its performances.

It is important to point out here that due to the lack of sufficient available data, the existing outfall is evaluated without extensive oceanographic survey. However, a reasonable evaluation was made possible on the basis of theoretical and practical considerations discussed in the literature consulted for this purpose, and the little information supplemented by Associate Consulting Engineers in Beirut.

Dilution of sewage effluent with the mass of sea water takes place first in the immediate proximity of the discharge point, then throughout the whole rising volume. Further mixing and dispersion occurs by wind-generated drifts current and by tarbulant mixed wave action.

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(2)
E.A. Pearson, "An Investigation of the Efficiency of Submarine Outfall Disposal of Sewage and Sludge," California State Water Pollution Control Board, Publication No. 14, Sacremanto, California (1956), pp. 54 - 55.

Assuming current nil, salinity distribution and water temperature uniform, Rawn and Palmer(3) in 1930 derived from their experiments the following emperical formulas:

For estimating the initial minimum dilution at the water surface along the axis of the rising jet:

$$S_o = \left[\frac{0.5\ (L_s + 3)^{2.35}}{Q^{\ 0.61}} \right] + 1 \qquad 5.1.$$

in which S_o, is the dilution factor at the point at which the jet axis meet the air-liquid surface; Q, refers to the quantity of flow of liquid effluent, in gallons per minute; and L_s, denotes the length of the rising jet measured from the point of discharge to air - liquid surface.

For estimating, L_s, they developed two cases:

Case I. When $\frac{Y}{X} > \frac{1}{3}$

$$L_s = Y + (0.8\ a)^{3/2} - \frac{0.1685\ a^2}{\sqrt[3]{y}} \qquad 5.2.$$

in which

$$X = \sqrt[3]{V^2 DY} \qquad 5.3.$$

$$a = \sqrt[3]{V^2 D} \qquad 5.4.$$

V = Discharge velocity

D = Discharge diameter

Y = Depth of water above outlet

Case II. When Y $\frac{Y}{X} < \frac{1}{3}$

$$L_s = X \left[1 + 0.9\ \left(\frac{Y}{x} \right)^2 \right] \qquad 5.5.$$

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(3) A.M. Rawn, and A.K. Palmer, "Predetermining the Extent of a Sewage Field in Sea Water" Trans. Am. Soc. Civil Engrs. 94 1036 (1930).

Figure 5.1. is a definition sketch illustrating the horizontal jet and the rising column of effluent at the point of discharge. All terms noted in the discussion refer to it for better understanding.

To evaluate the dilution factors, S, at any distance, X, from the center of rising ring, and to estimate the time, t, required for the sewage to travel a given distance from the column head, Rawn and Palmer approximated the following expressions:

$$S = So \sqrt{\frac{X}{X_o}} \qquad 5.6.$$

$$X_o \text{ (suggested)} = \frac{L_s}{8} + \frac{D}{24} \qquad 5.7.$$

$$t = \frac{2}{3\ F} X^{3/2} \qquad 5.8.$$

$$F = \frac{QSo}{2\pi \frac{L_s}{12} \sqrt{Xo}} \qquad 5.9.$$

In view of the presence of currents in the sea, Rawn and Palmer, have also estimated the maximum distance sewage will travel with the current by the following relationship.

$$e = X + UT \qquad 5.10.$$

where,

U = velocity of sea current.

T = time in seconds.

5.1.3. Sea Currents

Very little is known about currents in the vicinity of the existing outfall. This little information collected by Emery & George[4]

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(4) K.O. Emery and C. George, The Shores of Lebanon; Beirut: Catholic Press, 1963.

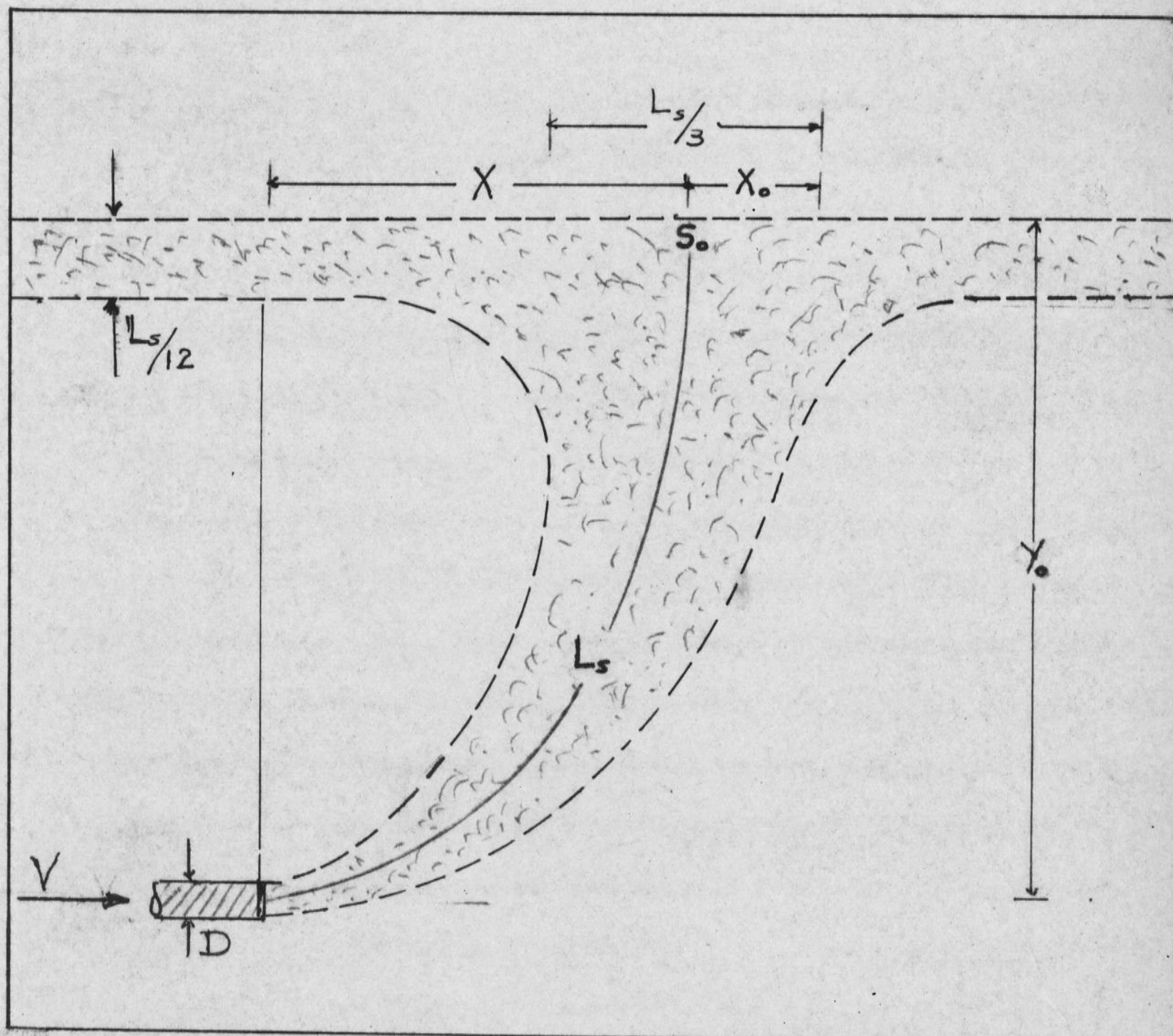

Figure 5.1. Definition sketch of rising column

After Rawn and Palmer

along the shores of Lebanon, do not give the highly desirable data on the movement of water currents to permit resolution of the circulating current pattern. Therefore, to evaluate the current pattern in the area under consideration reference is made to indirect methods and theories discussed in the literature.

Examination of the various discussions on currents and their characteristics indicates that currents are generally caused by wind, tide, horizontal density gradient, and waves.

Wind is the primary motive force for the development of currents in the area, whereas the relative or combined effects of all the other factors are assumed negligible and insignificant in developing currents in the area under study.

Wind records including direction and velocity for the 3-year period January, 1, 1957, to December 31, 1959, have been maintained at Tapline's oil terminal recording station near the Refinery. These data were collected by Associated Consulting Engineers, analyzed, summarized, and represented on a wind diagram as shown in Figure 5.2.

Limiting consideration to onshore winds characteristics, Figure 5.2. provides the following information:

	Onshore Winds		
Wind Direction	W	SW	NSW
Yearly Percentage	5.1	12.8	9.9
Speed in Km/hour	Average '8.25		

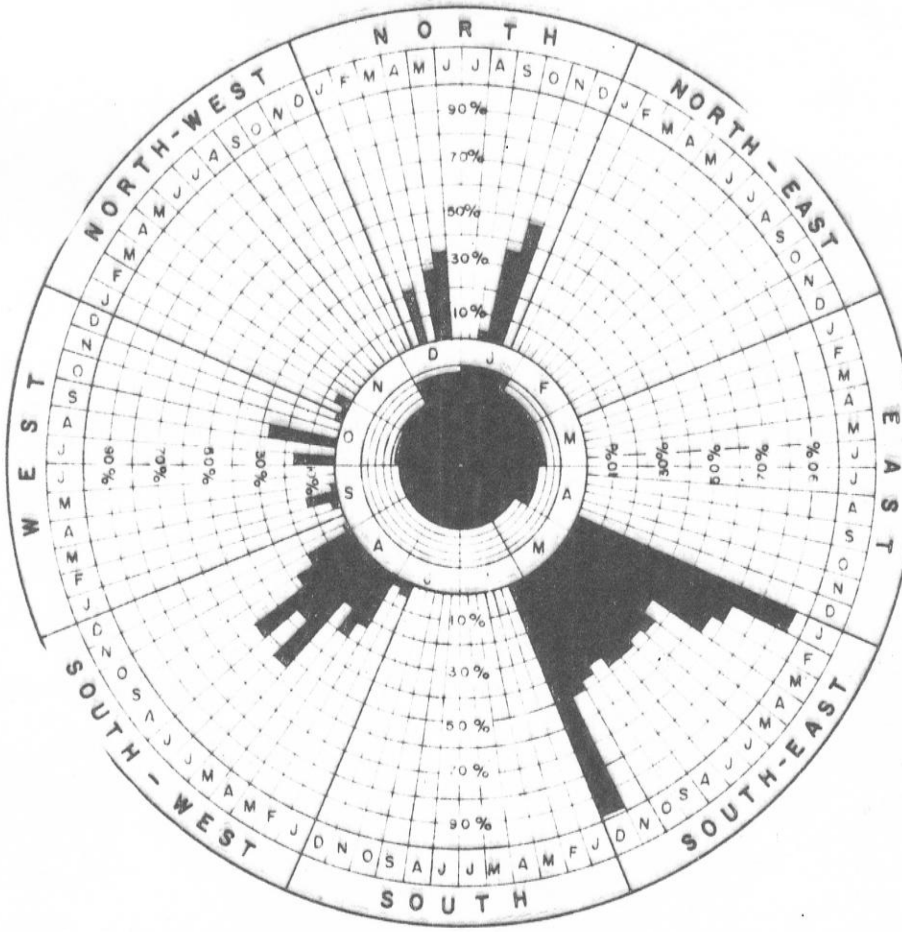

Figure 5.2. Wind pattern at refinery +

Remarks.

I. The outer big circle shows the yearly percentage of occurance of winds, and the direction from which they blow.
2. The inner small circle shows the mean wind speeds in Km. per hour.

+ The diagram is depicted from the preliminary report on Sidon City sewerage system prepared by Associated Consulting Engineers, Beirut.

Surface currents resulting from wind action were found by experiments to approach a velocity of:[5]

$$V = \frac{0.0127}{\sin Q} U \qquad 5.11.$$

where,

U = velocity of wind

Q = latitude

The direction of the wind-generated surface currents found by experimental studies to vary considerably. However, in the absence of better information, the direction of the current may be taken as 20° to the right of the wind direction,[6] though the underwater topography at the shoreline may vary this greatly.

Based on these empirical expressions and assuming the nearshore system of currents in the area under consideration do not markedly differ from those on which the experiments were based, then the expected surface currents direction and speed can be computed as follows:-

From equation 5.11.

$$V = \frac{0.0127}{\sin 37} \times 8.25$$

$$= 0.14 \text{ km/hr. or } 0.125 \text{ ft/sec.}$$

The directions of the onshore currents, which are assumed to deviate 20 degree to the right of wind direction, are shown on Drawing No. 1 in the Appendix.

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(5) E.A. Pearson, "An Investigation of the Efficiency of Submarine Outfall Disposal of Sewage & Sludge," California State Water Pollution Control Board, Publication No. 14, Sacremanto, California (1956), pp. 54 - 55.

(6) Ibid., p. 83.

5.1.4. Evaluation of the Existing Outfall

a) Hydraulic Considerations.

It is necessary at this point to determine the velocity, V, of the effluent which is to be discharged at a depth, Y, 6 feet below water surface, and at a location where direct onshore currents, U, of 0.125 ft/sec. is considered.

From the empirical expressions discussed in the previous section, it is readily observed that the dilution factor, S, is in direct proportion with the discharge velocity, V, and inverse proportion with the quantity of flow, Q. Therefore, at a constant pipe diameter, it becomes necessary to evaluate the outfall disposal objective at the maximum and minimum flows of sewage effluent.

With the predicted maximum daily flow of 8.3 gallon per minute (Section 5.1.1.) and a pipe outlet 12 inch in diameter the discharge velocity:

$$V\ max. = \frac{8.3 \times 0.14}{60\left[\frac{\pi \times (1)^2}{4}\right]}$$

$$= 0.02\ ft/sec.$$

With a predicted minimum daily flow of 2.5 gallons per minute (Section 5.1.1.) the discharge velocity:

$$V\ min. = \frac{2.5}{8.3} \times 0.02$$

$$= 0.006\ ft/sec.$$

Both velocities are extremely low due to the large pipe diameter and small quantity of flow. However, there is no limit on the minimum velocity, as the settleable solids in the effluent have been removed in septic tanks.

Hydraulic losses in the submerged sewer, 12 inches in diameter, discharging 8.3 gallons per minute of effluent at a maximum velocity of 0.02 ft/sec., are obviously very small and could be neglected. The main head loss is due to pipe friction, which is estimated from Figure 4.6, to be:

$$h_f = 100.2 \times \frac{0.03}{1000}$$

$$= 0.003 \text{ feet maximum.}$$

This value is rather small and is readily overcomed by the available head at point of submergance;

b) Dilution and Dispersion Considerations

From equation 5.3.

$$X \text{ max.} = \sqrt[3]{(0.02)^2 \times 1 \times 6}$$

$$= 0.13 \text{ ft.}$$

$$X \text{ min.} = \sqrt[3]{(0.006)^2 \times 1 \times 6}$$

$$= 0.06 \text{ ft.}$$

$$\frac{Y}{X} = \frac{6}{0.13} > \frac{1}{3}$$

From equation 5.4.

$$a \text{ max.} = \sqrt[3]{(0.02)^2 \times 1}$$

$$= 0.074$$

$$a \text{ min.} = \sqrt[3]{(0.006)^2 \times 1}$$

$$= 0.034$$

Therefore, the length, L_s, may be found from equation 5.2.

$$L_s \text{ max.} = 6 + (0.8 + 0.074)^{3/2} - \frac{0.1685 \times (0.074)^2}{\sqrt[3]{6}}$$

$$= 6.83 \text{ feet.}$$

$$L_{s\ min.} = 6 + (0.8 + 0.034)^{3/2} - \frac{0.1685 \times (0.034)^2}{3\sqrt{6}}$$

$$= 6.71 \text{ feet.}$$

From equation 5.7:

$$X_{o\ max.} = \frac{6.85}{8} + \frac{1}{24}$$

$$= 0.89 \text{ feet.}$$

$$X_{o\ min.} = \frac{6.71}{8} + \frac{1}{24}$$

$$= 0.87 \text{ feet.}$$

Hence, the distance to which the effluent will travel form the outlet to attain a dilution of 225, if there are no currents present, is found form equation 5.6:

$$X_{max.} = \left[\left(\frac{225}{14} \right)^2 \right] 0.89$$

$$= 230 \text{ feet.}$$

But, in view of the presence of currents, the distance the effluent will travel with the current is determined from equation 5.10, and the time, t, required for sewage to reach the periphery of the sewage field where $S = 225$ is determined from equations 5.8. and 5.9:

$$t = \frac{2 \times (230)^{3/2}}{\left(3 \times \frac{8.3 \times 0.14 \times 225}{2\pi \times \frac{6.83}{12} \times \sqrt{0.089}} \right)}$$

$$= 16 \text{ minutes.}$$

The total theoretical length, e, of the outfall required to satisfy the disposal objectives then becomes:

$$e = 230 + (0.125 \times 16 \times 60)$$

$$= 370 \text{ feet.}$$

Finally, in the case under consideration, where pollution is defined by the effect of bacterial count on neighboring bathing beaches, no problem is to be faced by discharging the sewage effluent under the conditions discussed, because the nearest bathing beach is about 2000 ft. away from the discharge point of the outfall. However, if new recreational beaches are established along the shoreline facing the refinery, then it becomes necessary to elongate the existing outfall sewer and re-evaluate its design criteria.

5.2. Solid Wastes

This section summarizes the problem of wastes containing solids, particularly oil-coated solids. It includes also a brief description of the sources and disposal practices associated with solid wastes.

5.2.1. Sources and Disposal Practices

At present, with the existing wastes treatment practices, the sources of solid wastes at the Refinery include:

a) Gravity separator bottoms.

b) Septic tanks sludge.

c) Detention pond bottoms.

d) Oil tank bottoms.

Additional sources of solid wastes include the air flotation froth expected from the recommended water reclamation plant.

Estimates of the quantities of solid wastes can be made from analysis of the waste water and from a knowledge of the removable matter produced by the different treatment processes. Estimates of the associated volume of water and oil is difficult to determine. Since detailed information is lacking as to the quantity and quality of the solid wastes derived from the foregoing sources, it is difficult to evaluate or design a disposal system to receive and dispose of the solid wastes properly.

The present practice of solid wastes disposal is accomplished by a single sludge basin measuring 25 ft. by 25 ft. and 1 ft. deep for sludge storage. All solid wastes from the foregoing sources are pumped to the basin and allowed to settle for reduction of volume. After prolonged settling, the oily water overflows and drains back to the separator while the partially dewatered sludge is conveyed and disposed of as fill in small pits along the shoreline and as close as 200 feet from it.

It is reasonable to conclude that the land disposal method adopted is not sound because of the following objectionable conditions that may arize:

a) The partially dewatered sludge which carries with it oil may, during stormy days, leach from the dump and contaminate the nearby sea water.

b) The associated oily water may infiltrate and contaminate underground water sources.

Therefore, it is recommended that this practice be changed and all sludge from the sludge basin be conveyed to the incinerator. The ash collected at the bottom of the incinerator is to be disposed in dumping areas.

The matters discussed in the text lead to the following conclusions:

a) The Medreco., Sidon Refinery, processing Saudi Arabian crude oil, has undergone continious expansion since the initiation of operations in 1955. There are great possibilities for future expansion. With such anticipated expansion, the additional problems which will confront the Refinery are the expected exploitation of ground water supplies, and the disposal of refinery wastes without contaminating the receiving waters. The gross quantity of water withdrawn at present amounts to 7 million gallons a day.

b) The Refinery does not have at present a record of water and waste water flows. The needed water is drawn from underground and the waste water produced is treated and disposed in the sea. Because of the lack of records, flows measurements were collected for a short period of time, the data was used in the design.

c) Because of the short period of study and the absence of problems associated with the rainy season, it was not possible to evaluate in detail the performances of each of the waste water treatment units. More detailed information on oil escape to the sea is needed in order to establish a realistic answer to shorline oil deposits. However, based on the data obtained it was apparent that the present wastes treatment plants are effective in maintaining the usefulness of the sea water adjacent to the Refinery and meeting water pollution control requirements.

d) At present, no legislation exists in Lebanon to control water pollution by industrial wastes, but the cooperative attitude of the Refinery management has shown all indications of effort to overcome all points of weaknesses in the waste treatment plants so that the systems satisfactorily take care and control sea water pollution.

e) With a slight change on the septic tanks design, the domestic sewage effluent is to continue discharging to the sea through the submerged sea outfall. In evaluating the existing outfall, all principal factors affecting the design were based on theories discussed in the literature cited. More practical information on the precise characteristics of the nearshore currents and water movements are needed for the successful completion of this study.

f) The projection of the number of employees and waste water flow rates into the future throughout the proposed design periods may be a valid approximation because the nature of the past records indicate inappripriation of any mechanical curve to be adopted to estimate the future figures.

g) Continuous pumping of ground water was attained even during dry seasons, without any evidence of water depletion or shortage. However, with the Refinery's expansion, ever-increasing demand for water, and over-pumping of ground water, the present situation may lead to a declining water table and possibly to the intrusion of sea water. To meet such situations reclamation of water from process waste water is desirable practice.

h) Reclamation of water from process waste water would save about 1 million gallons of water a day at an estimated cost of L.L. 0.02 per

1000 gallon, which is an economical means of obtaining more fresh water to meet the future demands, to help conserve fresh water shortages and to prevent over-extraction of under ground waters. More complete analysis is needed for re-estimating the unit cost of reclamation.

i) The reclaimed water, 700 gpm, is to be utilized for the direct uses of the Refinery such as, boiler feed, fire-protection, air-conditioning, plant clean-ups, lawn sprinkling, sanitary uses, cooling water, and miscellaneous other uses. The use, however, is limited to processes not handling products for human consumption.

j) Provision for maintenance, operation and periodic cleaning of the treatment units will be required to remove all solids settled in the various units. Routine tests of the flow characteristics of reclaimed water and raw process waste water should be performed at stated intervals.

k) Finally, this study should be regarded as a preliminary attempt to present the wastes and water problems encountered at the Refinery and to develop the necessary measures to overcome them.

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Drawing Nos. I, 2, and 3.

ADDENDUM

This project report was submitted before the defense committee on 30 October 1965. The committee accepted the project but criticized it as presented with regard to the following points which have been corrected or included herein as an addendum.

a) The approximate quantities of water used, consumed, and reclaimed are added to give an idea of the saving in ground water intake:

Total water in the system	(estimated)	=	7,200,000	g.p.d.
Total process water 15%	(average)	=	1,080,000	"
Total cooling make-up water	(estimated)	=	900,000	"
Total water intake		=	1,980,000	"
Total water reclaimed		=	1,008,000	"

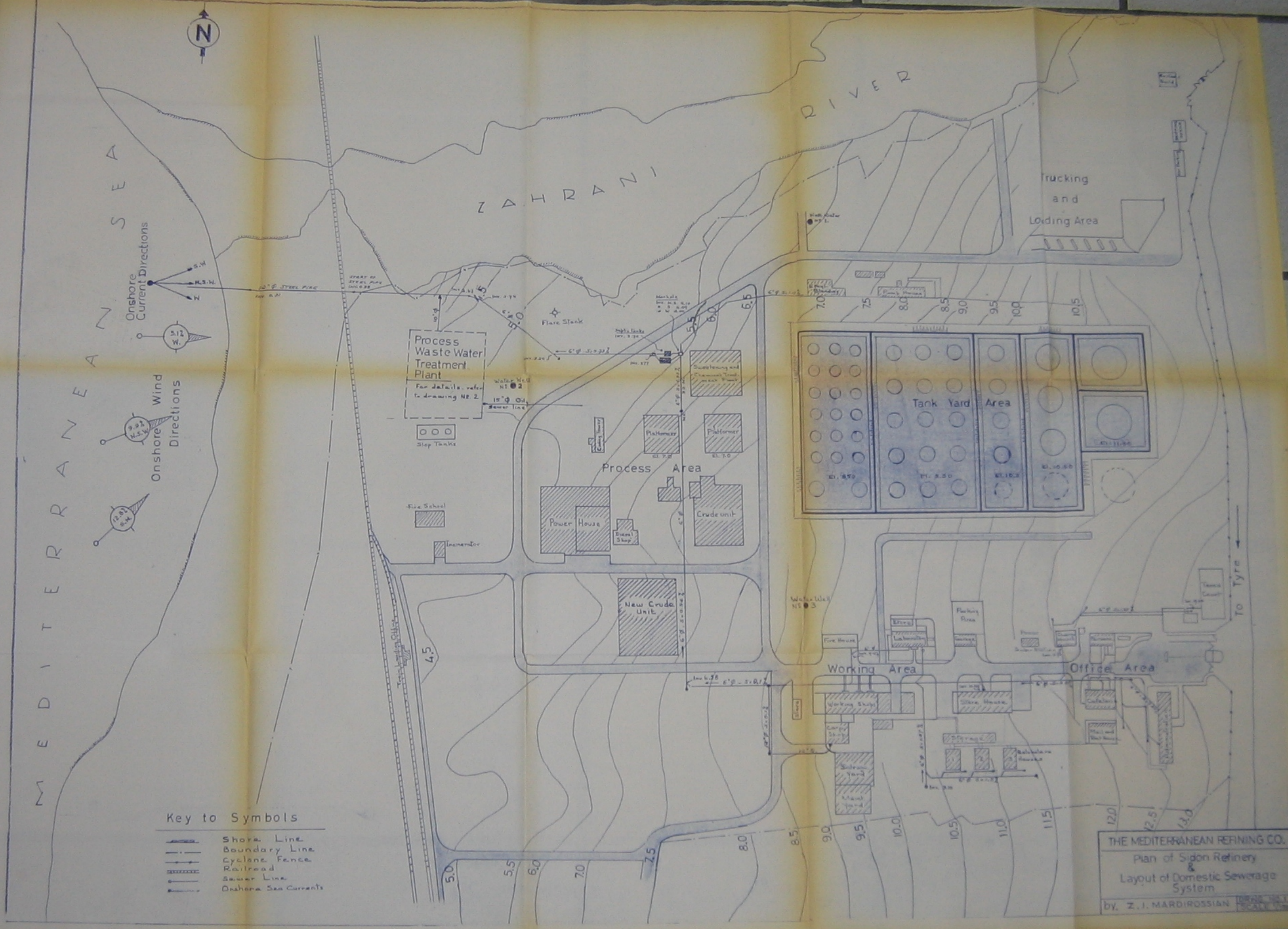
Percent reduction in underground water intake = 51%

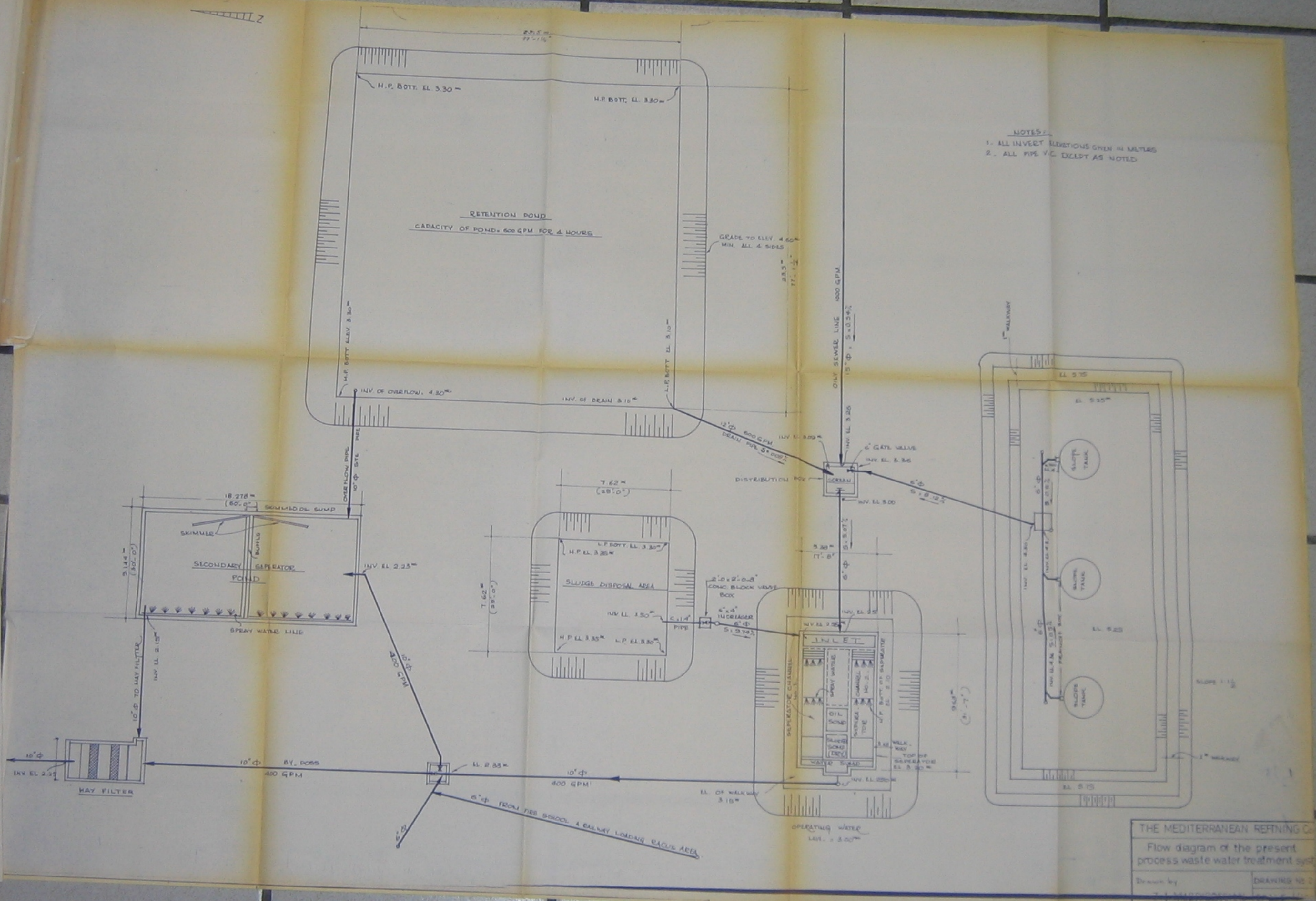
The cost of reclamation, including treatment and distribution expenses, averaged L.L. 0.02 per 1000 gallons, while, under the circumstances where sea water conversion becomes a must for fresh water supplies at a minimum cost of L.L.1.00 per 1000 gallons, then it is safe to say that the recommended scheme is a very economical means for fresh water supplies.

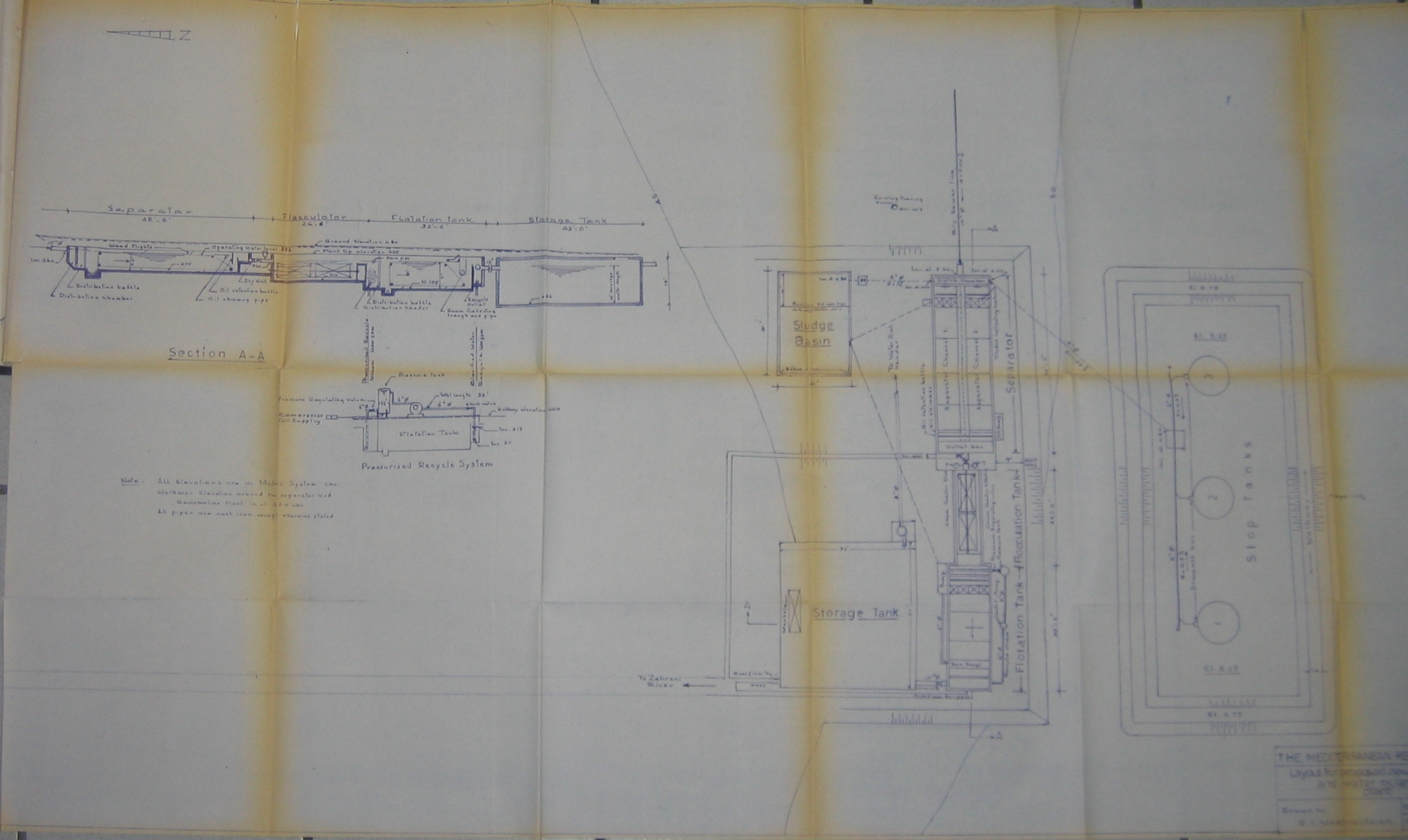
b) In replacing the existing plant units by the recommended plant, the following transition program is to be followed:

Before it reaches the primary separator, the process waste water is diverted totally to the detention pond wherefrom it is periodically siphoned to the secondary separator and passes through the other units of the existing plant. While the flow is diverted to the detention pond, the primary separator can be eliminated and replaced by the recommended separator plus the reclamation plant. When the new installation is placed in operation the detention pond and the hay filter unit can be eliminated.

c) In drawing No.3, the bottom of the storage tank is sloped 1/100 towards a corner to collect settleable solids in the corner sump for periodic pumpage and tank clean-up.


N
MEDITERRANEAN SEA
ZAHRANI RIVER
Onshore Current Directions
Onshore Wind Directions
Process Waste Water Treatment Plant
For details refer to drawing Nº 2
Slop Tanks
Flare Stack
Process Area
Platformer
Power House
Crude unit
New Crude Unit
Tank Yard Area
Trucking and Loading Area
Fire School
Incinerator
Working Area
Office Area
To Tyre
Key to Symbols
Shore Line
Boundary Line
Cyclone Fence
Railroad
Sewer Line
Onshore Sea Currents
THE MEDITERRANEAN REFINING CO.
Plan of Sidon Refinery & Layout of Domestic Sewerage System
by. Z. J. MARDIROSSIAN


RETENTION POND
CAPACITY OF POND = 600 GPM FOR 4 HOURS
H.P. BOTT. EL 3.30 m
GRADE TO ELEV. 4.60 m MIN. ALL 4 SIDES
INV. OF OVERFLOW 4.30 m
INV. OF DRAIN 3.10 m
L.P. BOTT. EL 3.10 m
OILY SEWER LINE 1000 GPM
12" Φ 600 GPM DRAIN PIPE
6" GATE VALVE
DISTRIBUTION BOX
SCREEN
OVERFLOW PIPE 10" Φ
SECONDARY SEPERATOR POND
SKIMMER
SKIMMED OIL SUMP
BAFFLE
SPRAY WATER LINE
INV EL 2.23 m
10" Φ 400 GPM
SLUDGE DISPOSAL AREA
CONC. BLOCK VALVE BOX
INLET
SEPERATOR CHANNEL No. 1
SEPERATOR CHANNEL No. 2
SPRAY WATER
OIL SUMP
SLUDGE SUMP
WATER SUMP
OPERATING WATER LEVEL
SLOPS TANK
10" Φ TO HAY FILTER
10" Φ BY PASS 400 GPM
10" Φ 400 GPM
HAY FILTER
6" Φ FROM FIRE SCHOOL & RAILWAY LOADING RACKS AREA
NOTES:
1. ALL INVERT ELEVATIONS GIVEN IN METERS
2. ALL PIPE V.C. EXCEPT AS NOTED
THE MEDITERRANEAN REFINING Co
Flow diagram of the present process waste water treatment syst
Drawn by
DRAWING No



Separator
Flocculator
Flotation tank
Storage Tank
Distribution baffle
Distribution chamber
Oil retention baffle
Oil skimming pipe
Dry Well
Distribution baffle
Distribution header
Scum Collecting trough and pipe
Section A-A
Pressure tank
Pressure Regulating valve
Flotation Tank
Pressurized Recycle System
Note.
Sludge Basin
Separator
Flocculation Tank
Flotation Tank
Storage Tank
To Zahrani River
Slop Tanks
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