

PROJECT STATUS PRESENTATION  
TO REGION II FOR  
POLLUTION ABATEMENT SITE  
OSWEGO, NY

APRIL 6, 1988

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## PURPOSE

Region II activated the Environmental Response Team to perform engineering studies on the Pollution Abatement Services site (PAS) leachate to determine the feasibility of installing a semiautomatic treatment system which would: 1) maintain a lower liquid level within the slurry wall, thereby protecting adjacent wetlands from leachate overflowing the slurry wall, and 2) eliminate or reduce the frequency of disposal, thereby reducing associated costs.

## SITUATION

The Pollution Abatement Services (PAS) site is a remediated Superfund site in Oswego, NY. Remediation of the site involved the removal of thousands of drums of hazardous wastes both above and below grade level. A slurry wall was constructed around the site perimeter to eliminate the migration of hazardous substances remaining in the soil. However, recent evidence suggests that leachate periodically overflows, or otherwise breaches, the slurry wall. To avoid this problem, it is necessary to lower the leachate level within the confines of the slurry wall every two to three months. This in turn necessitates the expenditure of time, money, and manpower to pump, transport and dispose of the leachate.

## TECHNOLOGY SELECTION RATIONAL

Three technologies will be explored via vendor treatability studies: 1) reverse osmosis (RO) with multiple pass treatment, 2) reverse osmosis with powdered activated carbon and microfiltration pretreatment (PAC/MF/RO), and 3) UV-oxidation.

Reverse osmosis employs a semipermeable membrane system that retains organic and inorganic solutes behind the membrane and allows solvent, water in this case, to permeate through the membrane. This separation creates two process effluent streams: a retentate containing the concentrated solutes and a permeate containing the filtered solvent-water. The permeate from the RO system (1st pass permeate) is then reprocessed in the RO system to remove residual contaminants, if necessary, resulting in 2nd pass permeate. Depending on treatment effectiveness, permeate can be discharged directly into a POTW or can be reinjected into the landfill to recharge and, thereby, flush the landfill. Another potential alternative is to polish the permeate with granulated activated carbon and mixed bed ion exchange resins, if necessary, for surface water discharge. The resulting reduced volume of concentrated organic and inorganic contaminants in the retentate can be treated off-site at a treatment, storage, and disposal (TSD) facility at an expected reduced cost. Figure 1 shows a schematic of a representative RO system.

In the reverse osmosis with powdered activated carbon with microfiltration system, powdered activated carbon (PAC) is mixed with the raw landfill leachate and mixed until most organics and some inorganics have had time to adsorb on the activated carbon. This mixture is subsequently filtered with a microfiltration (MF) unit to remove the PAC particles. The MF permeate is treated with a reverse osmosis system to remove any residual contaminants. The RO permeate can be discharged into a POTW, reinjected into the landfill, or discharged into surface waters as the permeate from the multiple pass RO system. Figure 2 shows a schematic of a representative PAC/MS/RO system.

A short comparison between microfiltration and reverse osmosis semipermeable membrane systems are presented below. Table 1 summarizes this comparison.

### Microfiltration (MF)

This semipermeable membrane separation technique encompasses the filtration of particles from 0.5 to 5 microns. The membrane consists of a number of pore which pass directly through the membrane. The pore are relatively uniform in size and occupy approximately 80% of the membrane surface.

### Reverse Osmosis (RO)

This semipermeable membrane separation technique encompasses the separation of inorganic salts and simple organic compounds under

pressure. The size of the species is in terms of molecular weight, and RO can be defined as the retention of solutes below 500 molecular weight. The RO membrane is a continuous gel. Separations are based on differential rates of diffusion. The small molecular species exhibit significant osmotic pressure across the membrane, resulting in high operating pressures.

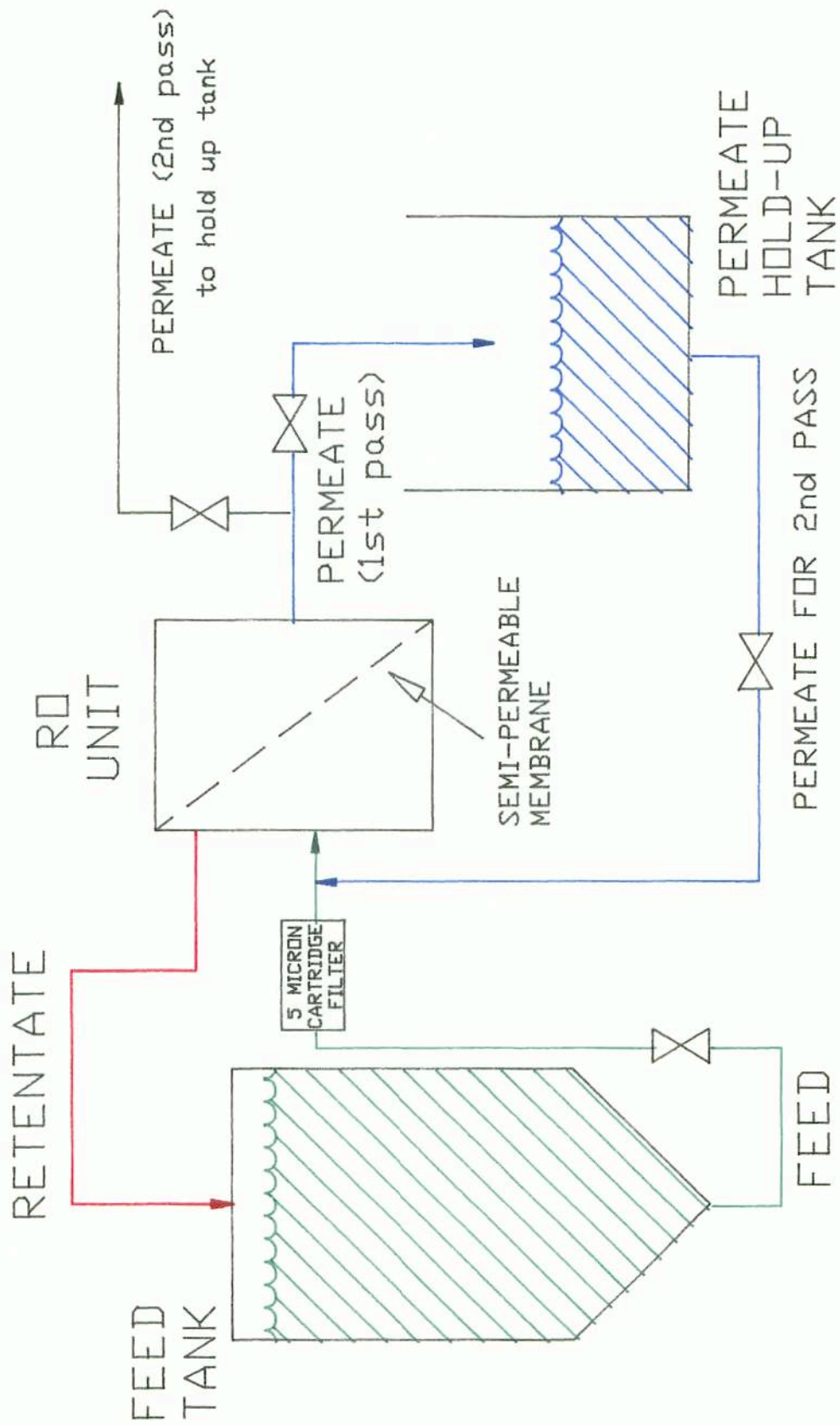
TABLE 1. COMPARISON OF REVERSE OSMOSIS & MICROFILTRATION CHARACTERISTICS

Microfiltration	Reverse Osmosis
o 0.5 to 5 micron cut-off	o below 500 MW cut-off
o porous membrane	o homogenous gel
o pore flow transport	o diffusive transport
o 20-100 psi operation	o 200-1500 psi operation
o rejection = f (pressure)	o rejection = f (pressure)

UV-oxidation degrades nearly all organic compounds into carbon dioxide, chlorine ions, and water. Organic compounds are degraded through the synergistic oxidation effects of UV photon and hydrogen peroxide or ozone. The systems have shown to be simple and effective for industrial wastewaters. The effluent can be reinjected into the landfill or polished with a mixed bed ion exchange resin for discharge to a POTW or surface waters. Figures 3 and 4 show a schematic of a representative UV-oxidation system.

These processes were selected on their previously successful applications for industrial wastewater/treatment.





REVERSE OSMOSIS (RO)  
TREATMENT SYSTEM

FIGURE 1.

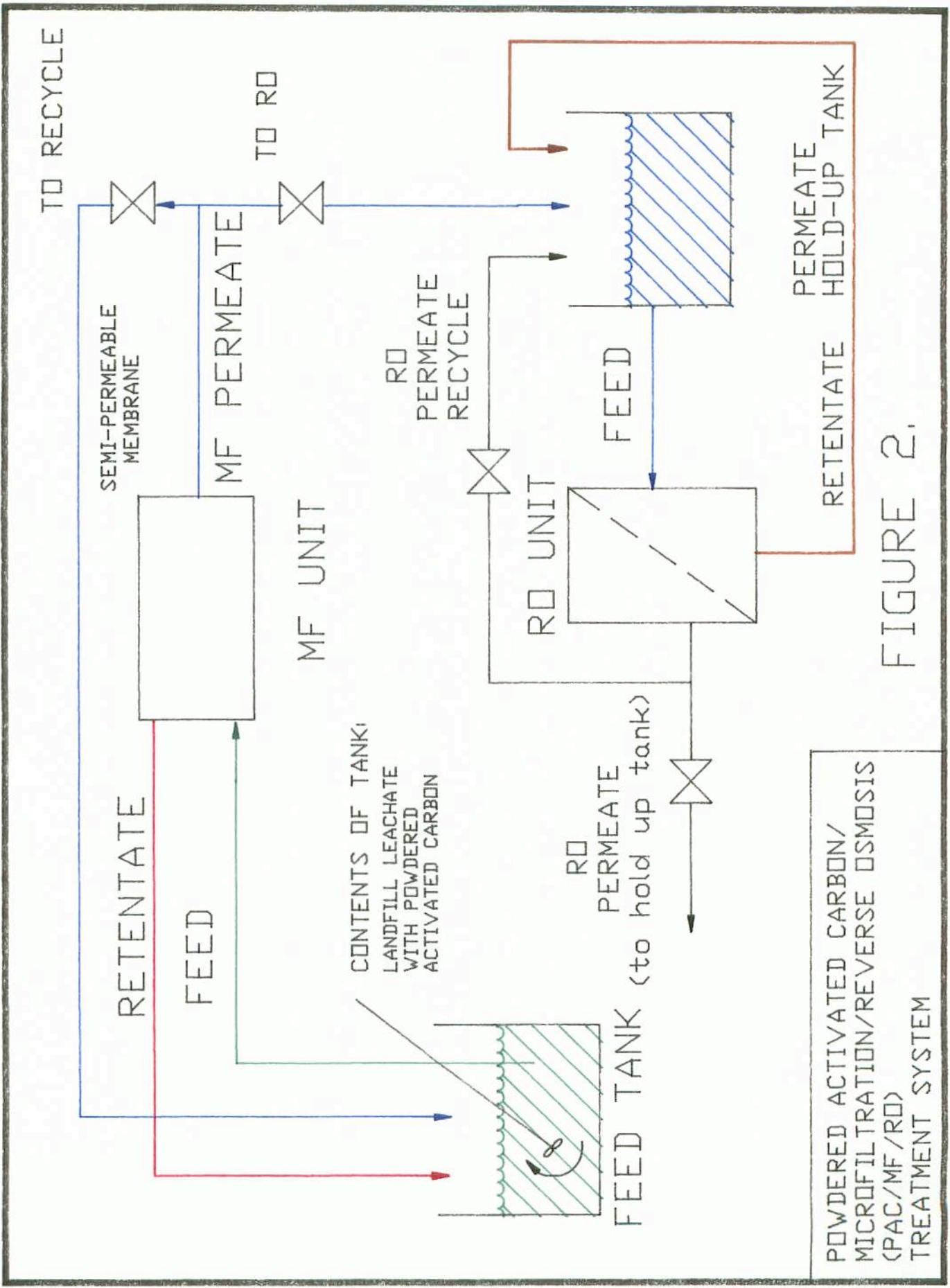
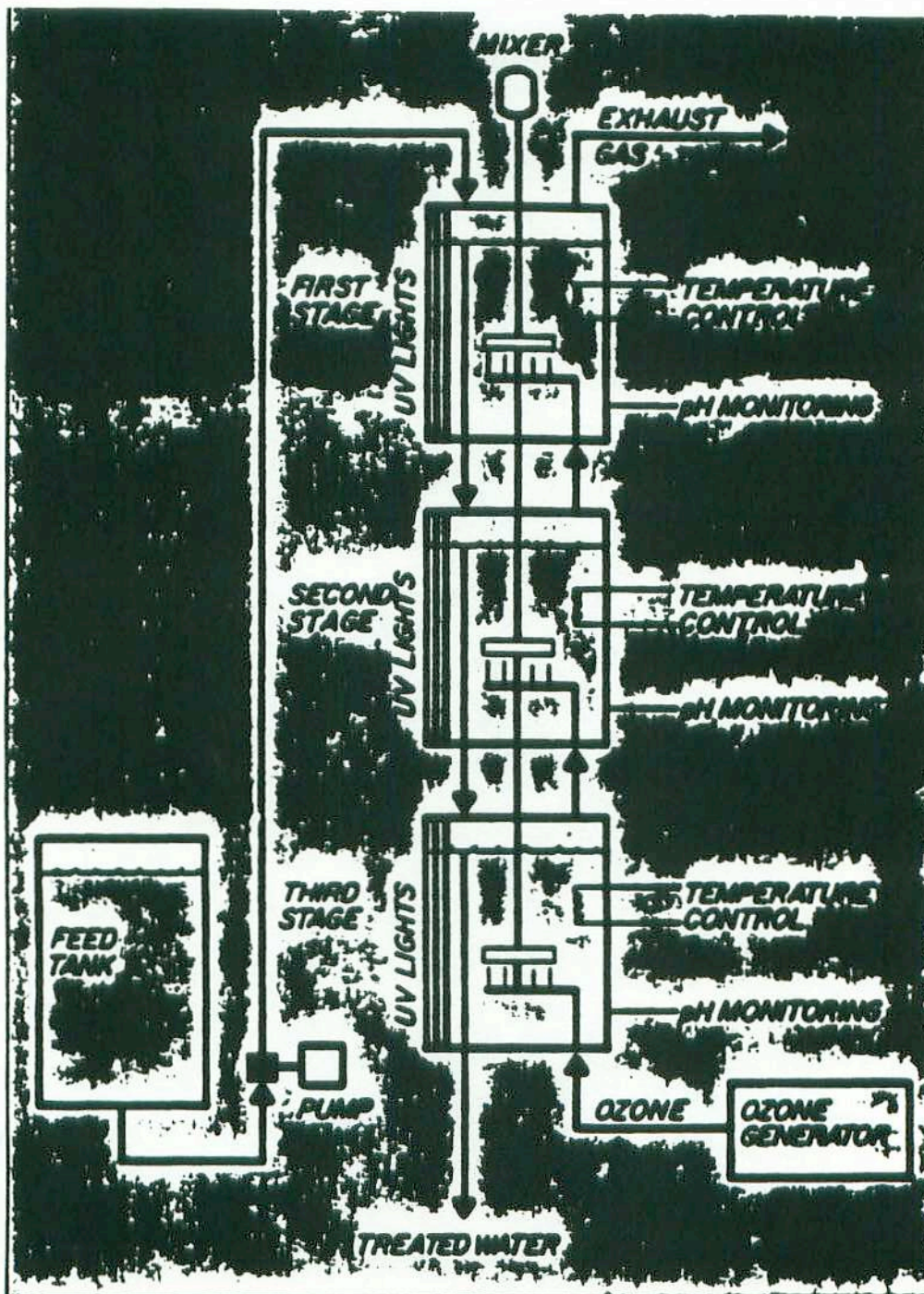


FIGURE 2.

FIGURE 3.  
UV-OXIDATION TREATMENT SYSTEM



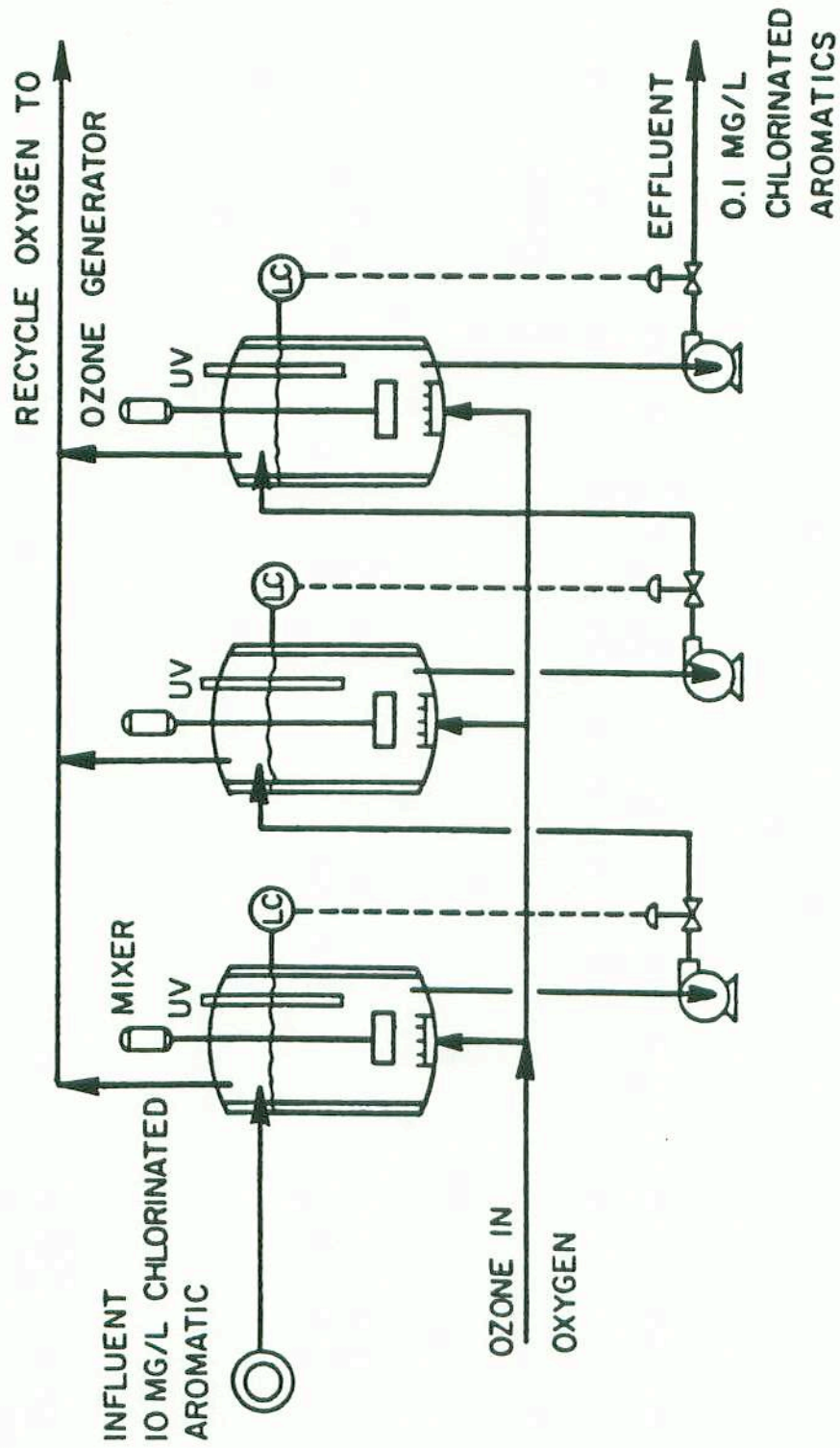


FIGURE 4. TYPICAL PROCESS FLOW, MIXED CHLORINATED AROMATICS

## TECHNICAL APPROACH

### SAMPLING AND ANALYTICAL

#### Sampling Plan

The objective of the sampling efforts was to obtain representative leachate from the in-ground storage tank at PAS. A sampling effort was performed on 18 December 1987 to obtain samples for leachate characterization. A later effort was carried out on 23 February 1988 to obtain the large sample volumes required for the UV-oxidation, microfiltration, and reverse osmosis engineering studies.

Before sampling, the leachate collection pumps were operated for approximately two hours to obtain fresh leachate and to mix leachate in the storage tank. The storage tank was sampled at the surface with a plastic bucket and immediately transferred into the appropriate containers for analysis. These containers were packed into coolers on-site, iced, and sent by overnight courier to an analytical laboratory.

The sampling effort for the engineering studies extracted approximately 100 gallons of leachate. Two 55-gallon drums, containing liners, were filled to total capacity to eliminate headspace and each placed in 85-gallon overpack drums.

#### Analytical Plan

The objective of the leachate analysis is to provide information for preliminary feasibility of the selected treatment options. The treatment system vendor, EPA Environmental Response Team (ERT) Work Assignment Manager (WAM), and Response Engineering and Analytical Contract (REAC) Task Leader (TL) will use the analytical data to determine the preliminary feasibility of selected treatment technologies for the PAS leachate. The analyses included:

- o total priority pollutants plus 40;
- o total suspended and dissolved solids;
- o titration curves (for total acidity);
- o pH;
- o TOC;
- o BOD;
- o COD; and
- o flashpoint.

Choice of analytical parameters from the samples taken at the subsequent engineering studies were dependent upon the results of the remedial investigation. Again, this choice was made jointly by the treatment system vendor, EPA/ERT WAM, and REAC TL. The analyses for the engineering studies included:

- o total priority pollutants plus 40 (except PCBs and pesticides);
- o priority pollutant metals plus iron and calcium;

- o sulfate;
- o cyanide;
- o total suspended and dissolved solids;
- o TOC; and
- o COD.

## VENDOR SELECTION

Several vendors were contacted for reverse osmosis (RO) treatment. The existence of other RO vendors will continued to be explored. RO vendors and the associated costs for treatability studies are:

- o Jack Holz and Associates, Fredricksburg, VA., Contact - Jack Holz, (703) 373-7466, charges \$750/day and a \$750 set-up fee plus membrane cost (\$375 maximum per membrane tape);
- o Osmonics, Inc., Minnetonka, Minn., Contact - Steve LaBarg, (800) 351-9008, charges \$750/day, plus membrane cost (\$450 maximum per membrane type); and
- o Environment Canada, Ottawa, Ontario, Contact - Harry Whittaker, (613) 998-9622, charges no fee for the study except \$1000 for membrane costs.

Environment Canada (EC) has developed a unique expertise in the RO treatment of CERCLA type aqueous wastes, has specialized in field cleanup of contaminated aqueous waters, and has several mobile treatment units available for use (see Figures 5, 6, and 7). In addition, EC has offered free use of their portable reverse osmosis unit, except for a membrane usage fee and labor, a significantly lower cost than competitive vendors; hence, they were selected for the RO study.

Environment Canada also has bench scale UV-oxidation equipment so these studies will also be performed at their Ottawa facility at little or no extra cost to EPA.

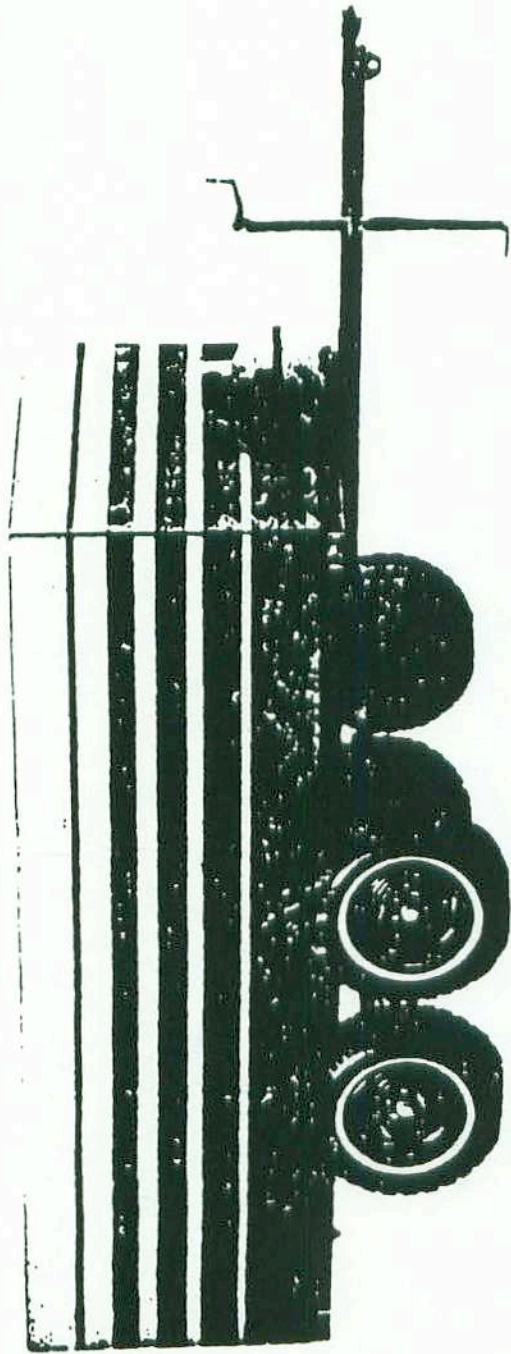


FIGURE 5. EPS MOBILE REVERSE OSMOSIS UNIT



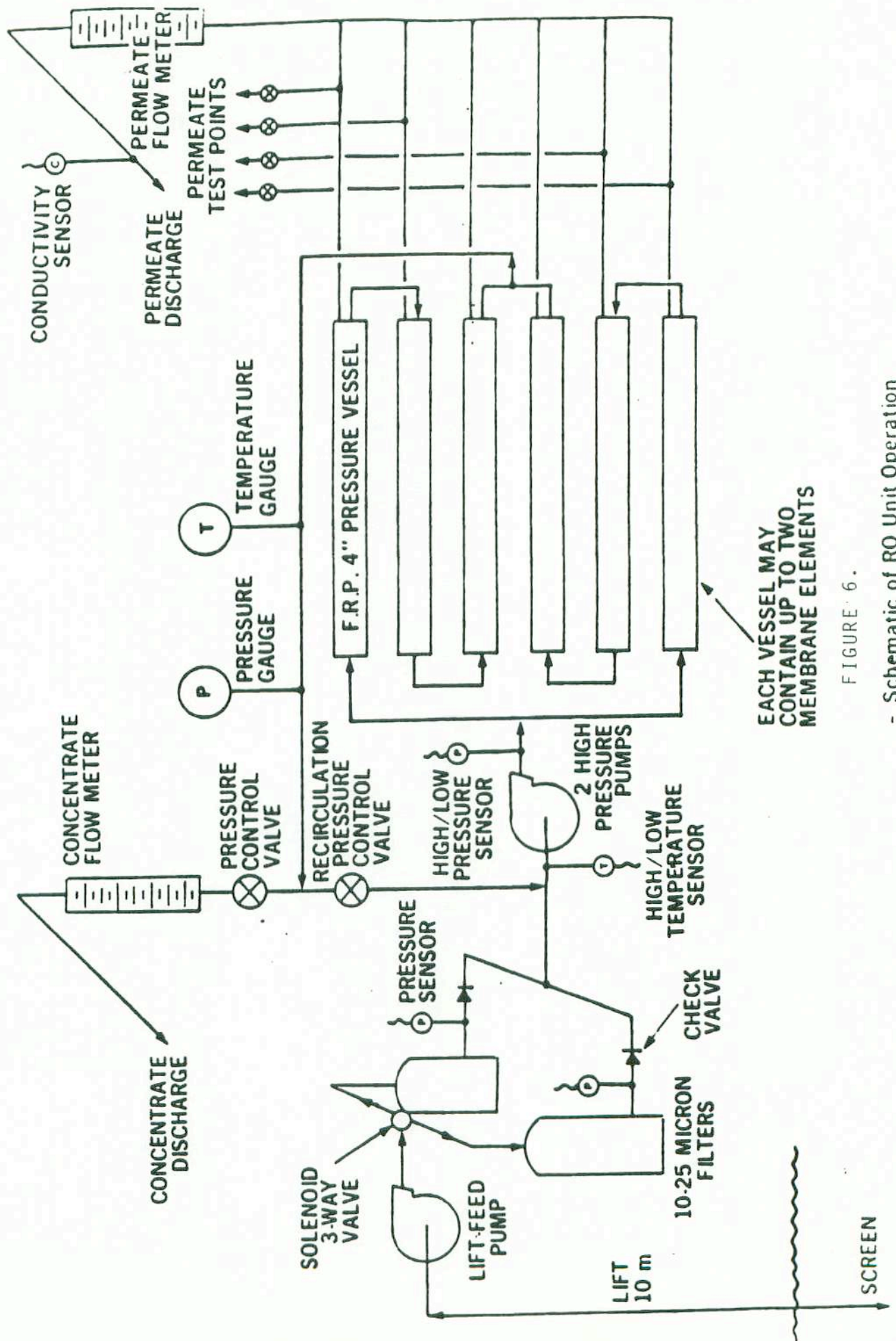
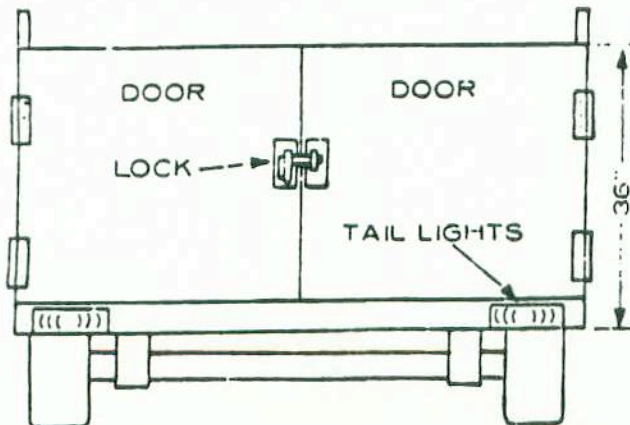
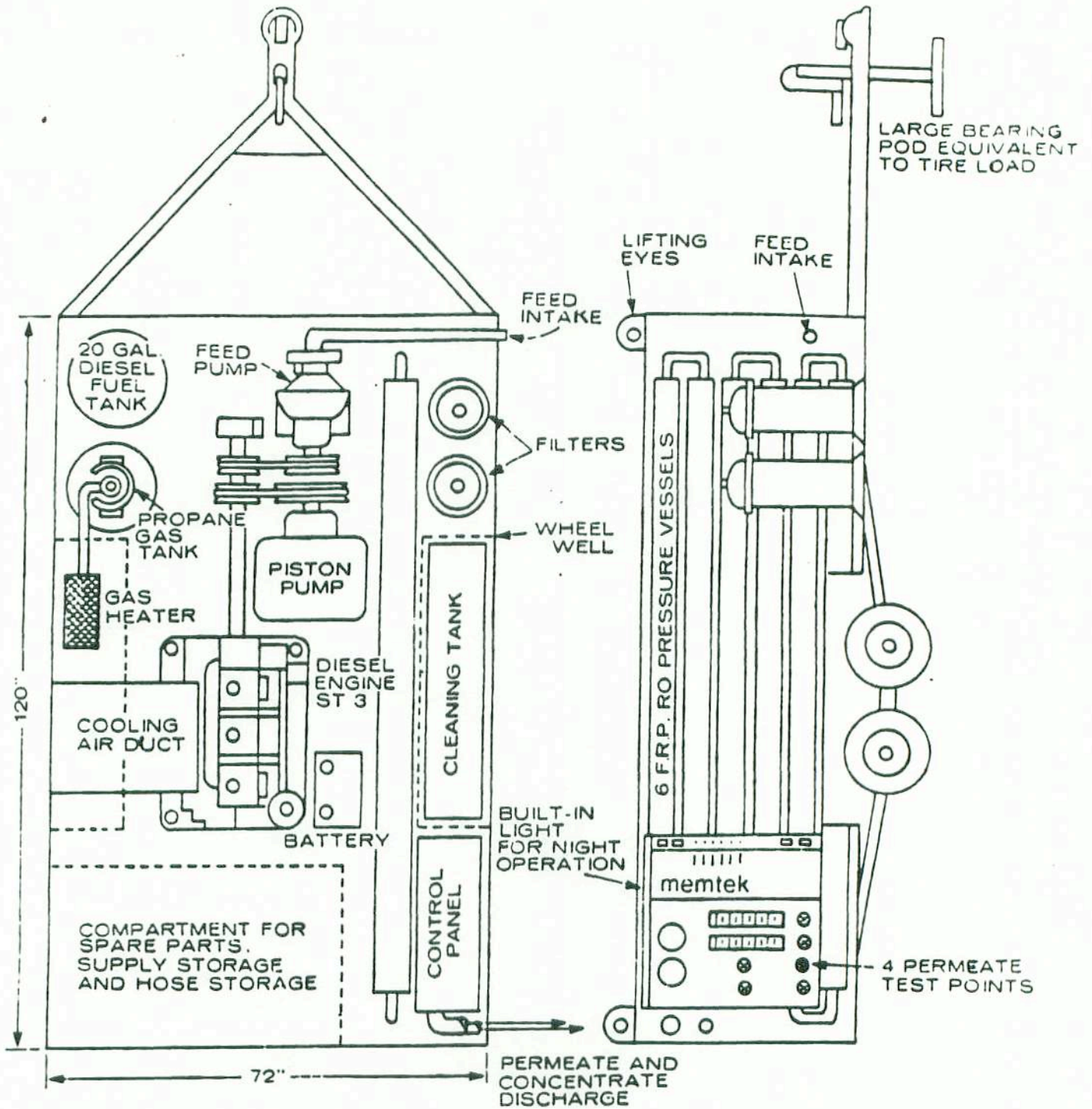


FIGURE 6.

- Schematic of RO Unit Operation



NOTE: SKIN AND DOORS FOR CONTROL PANEL, FILTER HOUSINGS, CLEANING TANKS AND FUEL TANKS OMITTED FOR CLARITY

FIGURE 7.

- Reverse Osmosis Unit Layout

## ENGINEERING STUDIES

Treatability studies will commence after a review of the analytical data obtained from the sampling effort. Vendors, WAM, and TL will review data and determine preliminary feasibility and expected success of the engineering studies to be performed. These studies will be explored, first, at the vendor's or the EPA Edison facility - Phase I. Later, if Phase I indicates a technically and economically feasible alternative has been found to off-site treatment, on-site Phase II engineering studies will commence in Oswego, NY.

The following questions must be answered by the engineering effort:

- o What are the costs of the on-site processes used for waste treatment? How do these costs compare with total treatment in an off-site TSD facility? An economic evaluation will be performed as part of the feasibility study to answer these questions. This evaluation will include treatment vendor costs, estimated ERCS costs for on-site treatment vs. off-site treatment, transportation, utility consumption, chemical consumption, and disposal.
- o What is the effectiveness of UV-ozonation on the leachate treatment? How much treated leachate will be discharged? What is the residual contaminant levels of the treated leachate? These questions will be explored during the engineering study.
- o What is the wastewater volume reduction of RO? What is the volume of the retentate remaining from RO? The highest concentration ratio (the measured volume of the feed divided by the volume of the retentate) that the reverse osmosis system can effectively operate without a severe permeate flux reduction will give us this information.
- o The concentration of contaminants in influent and all effluent streams for the treatment systems will be examined. An analysis of these streams only for those contaminants present and of interest (after a review of the Phase I sample analysis data) will be performed. All analysis will be in compliance with NY DEC and EPA Region II requirements and will be performed by the Phase I analytical subcontractor.
- o Can the treatment system effluent be discharged into surface waters? The results of the engineering study will be given to EPA Region II and NY DEC for their evaluation. The results will include effluent contaminant concentration, volumetric discharge, on-site effluent storage scheme and capacity, and discharge duration.
- o What is the duration of on-site, fullscale treatment for each process? This will be estimated from treatment system capacity, wastewater volume and start up time.
- o How often does the reverse osmosis unit have to be cleaned and can it be cleaned effectively? This question will be thoroughly explored during the treatability study using various cleaning agents.

- o What affect will winter temperature at the site have on the on-site, fullscale treatment systems? An evaluation of this question will be made by the vendor engineer, the WAM and the TL. If a potential problem exists, a contingency plan will be devised to remedy the situation.

If engineering studies prove target treatment technologies effective and economical, on-site treatment will be recommended, otherwise continued off-site treatment at a Treatment, Storage and Disposal (TSD) facility will be the treatment option of choice.

The Weston/REAC Task Leader (TL), Robert Evangelista, will maintain contact with the EPA Work Assignment Manager (WAM), Thomas Kady, to keep him informed about the technical and financial progress of this project. The TL will be responsible for all subcontractor work, for organizing any additional sampling efforts and for reports. Activities under this project will be summarized in appropriate format for inclusion in REAC Monthly and Annual reports.

## PROJECT SCHEDULE

Work on this assignment will commence on 17 December 1987. The duration of the assignment will be approximately 7 months or 10 months for completion of Phase I and Phase II, respectively. A REAC Project Summary Schedule (Table 2) lists the completed tasks and forecasted duration of activities.

The project tasks have been divided into 3 sections: 1) remedial investigation, 2) Phase I engineering studies, and 3) Phase II engineering studies.

Remedial investigation tasks include:

- o development of work plan,
- o review of previous site information,
- o site sampling for waste characterization,
- o sample analysis, and
- o preliminary technical evaluation.

Phase I engineering studies tasks include:

- o sampling for treatability study,
- o transport samples,
- o vendor studies off-site,
- o sample analysis,
- o feasibility and economic analysis,
- o decision point, and
- o a final report if the decision is negative.

If the evaluation of the Phase I studies is positive, the Phase II engineering studies tasks include:

- o vendor on-site studies,
- o sample analysis,
- o data evaluation,
- o final report.

A written final report that includes raw data will be supplied to the EPA Work Assignment Manager to make recommendations to the EPA On-Site Coordinator.

TABLE 2  
 REAC PROJECT SUMMARY SCHEDULE  
 POLLUTION ABATEMENT SERVICES  
 LEACHATE TREATMENT STUDY  
 EPA MARK ASSISTMENT NO. 6-83

LEGEND  
 ))) ACTIVITY BURSTION - FORECAST  
 C COMPLETED TASK

TASK NO.	DECEMBER 1987	JANUARY 1988	FEBRUARY 1988	MARCH 1988	APRIL 1988	MAY 1988	JUNE 1988	JULY 1988	AUGUST 1988	SEPTEMBER 1988	OCTOBER 1988	NOVEMBER 1988	DECEMBER 1988	JANUARY 1989	FEBRUARY 1989	MARCH 1989
REMEDIAL INVESTIGATION :																
11. DEVELOP MARK PLAN		C														
12. SITE INFORMATION REVIEW		C														
13. SITE SAMPLING		C														
14. SAMPLE ANALYSIS			C													
15. PRELIMINARY TECHNICAL EVALUATION				IC												
16. PHASE I ENL STUDIES :																
16.1. SAMPLING FOR TREATABILITY STUDY																
17. TRANSPORT SAMPLES																
18. VENDOR STUDIES OFF-SITE																
19. SAMPLE ANALYSIS																
20. FEASIBILITY AND ECONOMIC EVALUATION					))))))))))))))))											
21. EPA DECISION							))									
22. IF EVALUATION IS NEGATIVE, FINAL REPORT							))))))									
23. PHASE II ENL. STUDIES IF EVALUATION POSITIVE :								))))))))								
23.1. VENDOR ON-SITE STUDIES								))))))))								
24. SAMPLE ANALYSIS								))))))))								
25. DATA EVALUATION								))))))))								
26. FINAL REPORT								))))))))								

TRIP REPORT OF STUDIES AT ENVIRONMENT CANADA

TO: Tom Kady, EPA Environmental Response Team,  
Work Assignment Manager

FROM: Robert Evangelista, Weston/REAC, Project Engineer

THRU: Mike Skirka, QA/QC Officer

SUBJECT: ENGINEERING STUDIES AT ENVIRONMENT CANADA, OTTAWA, ONTARIO

DATE: March 5, 1988

Tom, attached is the Trip Report on the pilot-scale engineering studies performed at Environment Canada, River Road Environmental Testing Center, Ottawa, Ontario. These studies explored the filtration, concentration, or destruction of contaminants in the landfill leachate from the Pollution Abatement Services site, Oswego, NY, using three technologies: reverse osmosis, powdered activated carbon/microfiltration pretreatment with reverse osmosis, and UV oxidation.

This report details the testing of reverse osmosis and powdered activated carbon/microfiltration with reverse osmosis tests. UV oxidation tests will be performed in the immediate future and a future report will cover this test.



TRIP REPORT  
ENGINEERING STUDIES WITH POLLUTION ABATEMENT SERVICES (PAS),  
OSWEGO, NY LANDFILL LEACHATE AT ENVIRONMENT CANADA

## INTRODUCTION

On February 23, 1988, two 55-gallon drum samples were taken from the Pollution Abatement Services site (PAS) in Oswego, NY, under the auspices of NY Department of Environmental Conservation (DEC) representative, Dick Brazell. These samples were transported to Environment Canada (EC) Ottawa, Ontario for engineering studies of leachate treatment. From February 24th to 27th, 1988, several cleanup techniques were explored on this landfill leachate under the direction of Harry Whittaker at Environment Canada's River Road Environmental Testing Center in Ottawa, Ontario. A preliminary analysis of the leachate prior to treatment is shown in Sample 0, Appendix 1 of this report. The treatment methods utilized consisted of:

1. Addition of Powdered Activated Carbon (PAC) system to the leachate followed by membrane separation and concentration with tubular Microfiltration (MF) and spiral wound Reverse Osmosis (RO).
2. System raw waste was pretreated with 5 micron polypropylene filters to remove large particulates and subsequently was processed by RO. The RO permeate from this treatment was pretreated by RO to produce second pass permeate.
3. UV - oxidation of the leachate.

In the first two cases, hydrochloric acid was added to the leachate prior to treatment to lower the pH to between 5 and 6. Since the orange color of the raw leachate indicated that it contained iron, this iron would tend to precipitate out when the waste was concentrated by RO, and deposit on the membranes causing fouling if the pH of the waste were not maintained between 5 and 6.

The purpose of those tests with Systems 1 and 2 was to retain and concentrate the contaminated landfill leachate while generating relatively contaminant-free permeate (filtrate). The purpose of the test with System 3 was to eliminate all organics from the leachate. The following definitions should be noted in this report: retentate or concentrate is that material that is retained or concentrated by a semipermeable membrane such as MF or RO; and permeate or filtrate is that substance which permeates or passes through the membrane.

## SYSTEM ONE - PAC/MF WITH RO

### Operations and Testing

The PAC/MF with RO (see Figure 8) process was tested to determine how well PAC/MF would pretreat the waste to prevent fouling of RO membranes. However, since the waste contained a large number of both organic and inorganic compounds, it was recognized that PAC addition followed by MF alone would probably not be sufficient to completely treat the waste. In addition, the process could prove more cost effective to pretreat the wastes in this manner as compared to conducting double pass RO (that is, treating the permeate from the first pass again). This is due to the lower power requirements (since lower operating pressures are used) and the higher filtrate flux rates with tubular membranes.

The test procedure was as follows:

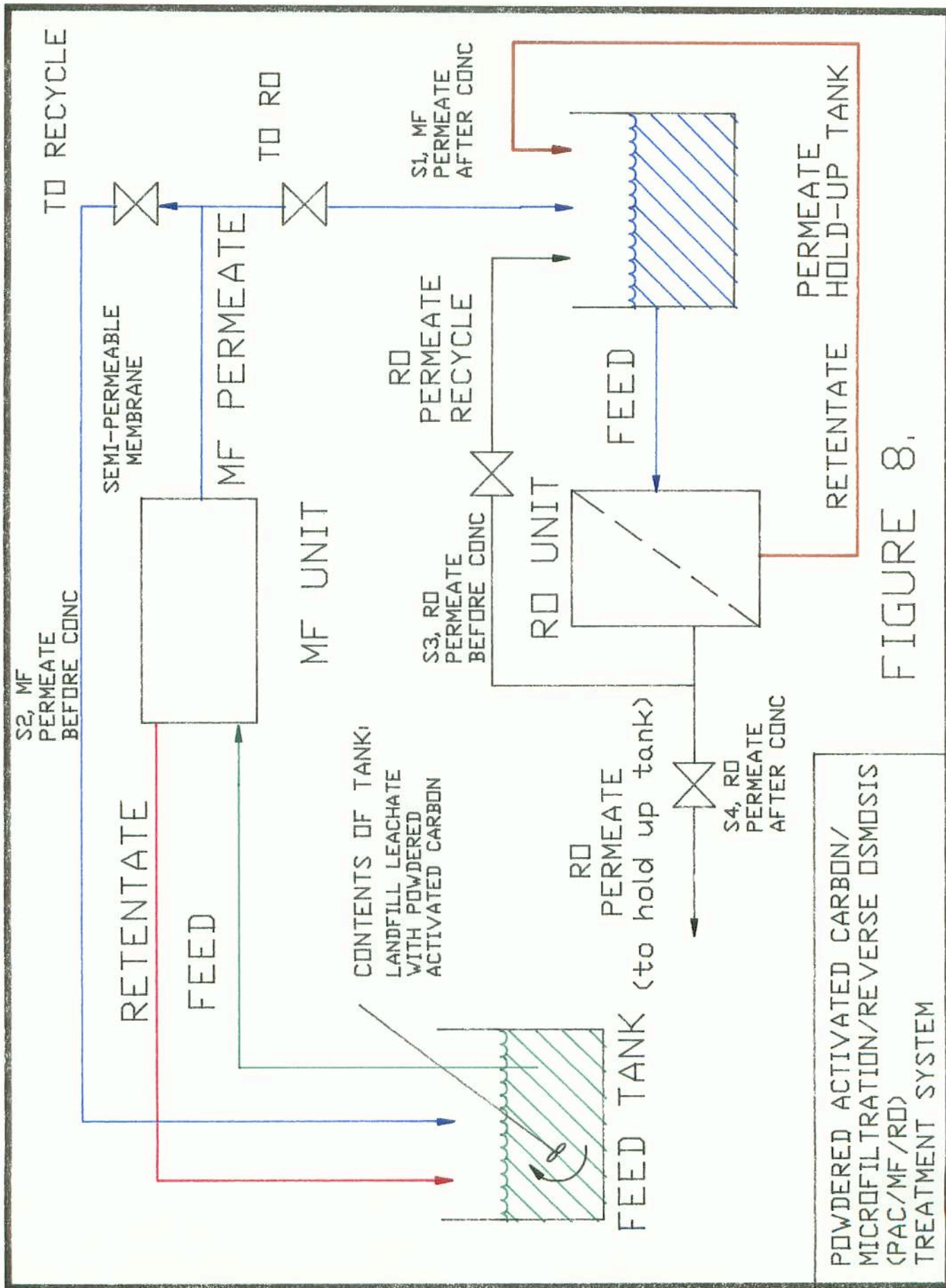
1. PAC (5 g/L) and 400 mL concentrated hydrochloric acid (HCl) were added to approximately 55 gallons (200 liters) of the raw waste and the mixture was stirred by a submersible pump for three hours to allow contaminants to adsorb on the carbon.
2. The MF unit was operated for two hours with the permeate recycling to the feed tank, i.e., no concentrating, to allow the permeate flow rates to stabilize. A sample of the filtrate (Sample #2) was taken by EPA after 120 minutes of operation. Readings taken during this portion of the trail are shown in Table 3. Table 5 contains the parameters analyzed in all samples.
3. Next, the leachate was concentrated to one-fifth of its former volume (5 X concentration). After concentration of the feed, a sample of the filtrate was taken (Sample #1).
4. Two new TORAY RO spiral wound membranes were conditioned with the filtrate from the MF test. This filtrate was recirculated through the RO unit at 400 psi for one hour. Next, the pressure was slowly raised over 40 minutes to an operating pressure of 800 psi. Throughout this operation the RO permeate was recycled into the feed tank to maintain a 1 x concentration. Sample #3 was taken of the RO permeate prior to concentration. The filtrate was then concentrated down to one quarter (4x) of its former volume and Sample #4 of the RO permeate was taken.

TABLE 3. READINGS FROM PAC/MF TREATMENT

Time (min)	MF Permeate Flow Rate (Lpm)	Temperature (°C)	Pressure (psi)
0	9.74	12.0	43
10	10.40	13.5	43
20	10.62	15.0	43
40	11.65	16.0	43
80	12.77	20.0	43
100	13.36	22.0	41
120	16.81	24.0	42

### Result

Treatment by PAC/MF resulted in a clear and colorless filtrate, but the filtrate had a distinct odor and foamed when shaken. In addition, when sodium hydroxide (NaOH) was added to a sample of the MF filtrate, an orange color appeared indicating that little iron (and probably other inorganics) had been removed by MF. The RO permeate that resulted from the processing of the MF filtrate had no odor, foamed very little, and showed no color change when NaOH was added. RO permeate flow rates were fairly constant, starting at 4.0 Lpm at 1 x concentration and decreased slightly during concentration by RO to 3.5 Lpm at 4x.



## SYSTEM TWO - REVERSE OSMOSIS

### Operations and Testing

In this case, approximately 55 gallons (200 L) of the raw waste were transferred to a stainless steel tank and 400 mL of concentrated HCl was added to reduce the pH to 5-6. The process schematic is shown in Figure 9. The feed line to the RO unit was simply transferred to the permeate collection barrel to accomplish a second pass of the RO permeate through the system.

The procedure followed for the testing with RO was as follows:

1. Sample #5 of the raw feed was taken after transfer with a hand operated diaphragm pump. HCl (400 mL) was added to the feed during the transfer to the stainless steel tank.
2. The raw feed was circulated through the RO unit for one and a half hours at an operating pressure of 800 psi with the permeate recycled to the feed tank maintaining 1 x concentration to determine permeate flow rate stability. Flow rates observed during this period are shown in Table 4. Sample #6 of the permeate was taken after recycling.
3. The feed was concentrated to approximately 4x. Sample #7 of the permeate and #9 of the concentrate were taken at maximum concentration.
4. The permeate removed from the feed during the above concentration procedure was then reprocessed by the RO unit to produce second pass permeate. Sample #8 was taken of the second pass permeate to distinguish if any difference existed between first pass permeate.

### Results

The first pass permeate had visual quality comparable to the filtrate that had been processed by PAC/MF/RO in the previous testing; there was no visible improvement in the second pass permeate over the first pass permeate. There was no indication that the membranes were fouling during this run as the permeate flow rates remained constant over the trial (see Table 4). This would signify that the 5 micron filters were sufficient to remove large particulates that would otherwise deposit on the membranes. However, it will be necessary to conduct much larger scale trials to accurately learn how much down time would be necessary for membrane cleaning if the system were to be operate for longer periods of time while processing larger volumes of waste. The results from this testing show that no pretreating (aside from coarse prefilters) is necessary to treat this waste by RO. It should also be noted that no color changes were noted in the permeate when NaOH was added to it, indicating that iron, and probably most other inorganics, were removed along with the organic compounds.

TABLE 4. READINGS FOR RO TREATMENT

Time (min)	Perm Flow Rate (Lpm)	Conc. Flow Rate (Lpm)	Pressure (psi)	Temp (C)
0	4.0	4.5	790	10.0
20	4.5	4.5	790	11.5
30	4.5	4.5	790	12.0
50	5.0	4.5	790	13.0
75	6.0	4.3	785	14.5

Appendix contains preliminary GC work by EC (note that peak identities and peak areas are not included).

TABLE 5. DESCRIPTION OF SAMPLES TAKEN DURING ENGINEERING STUDY  
AT ENVIRONMENT CANADA

Sample #	System Samples	Liquid Stream Sampled	Analytical Parameters	Laboratory
1	PAC/MF/RO	MF permeate after concentration	pp + 40 <sup>a</sup> , Fe, Ca, SO <sub>4</sub> , TSS, TDS, CN	Envirotech
2	PAC/MF/RO	MF permeate after recycling and before concentration	pp metals <sup>b</sup> , Fe, Ca, misc. organics	Envirotech EC <sup>c</sup>
3	PAC/MF/RO	RO permeate after recycling and before concentration	pp metals, Fe, Ca, misc. organics	Envirotech EC
4	PAC/MF/RO	RO permeate after concentration	pp + 40, Fe, Ca, SO <sub>4</sub> , TSS, TDS, CN	Envirotech
5	-----	Raw landfill leachate	pp + 40, Fe, Ca, SO <sub>4</sub> , TSS, TDS, misc. organics	Envirotech EC
6	RO	RO permeate after recycling and before concentration	pp metals, Fe, Ca, misc. organics	Envirotech EC
7	RO	RO permeate after concentration, first pass	pp + 40, Fe, Ca, SO <sub>4</sub> , TSS, TDS, CN, misc. organics	Envirotech EC
8	RO	RO permeate, second pass	pp + 40, Fe, Ca, SO <sub>4</sub> , TSS, TDS, CN, misc. organics	Envirotech EC
9	RO	RO leachate retentate after concentration	pp metals, Fe, Ca, misc. organics	Envirotech EC

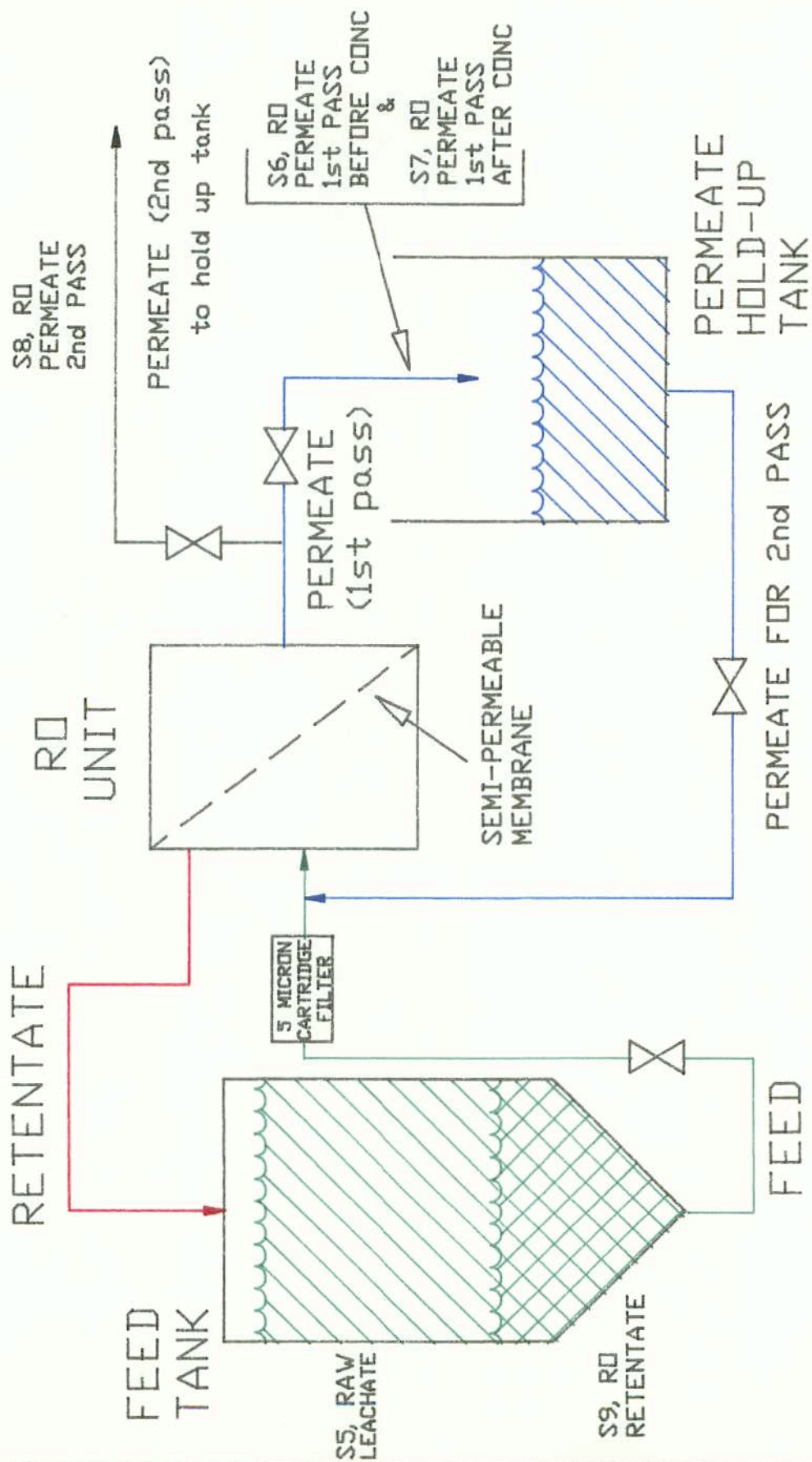
<sup>a</sup> pp + 40 = priority pollutants + 40 (does not include PCB's and pesticides).

<sup>b</sup> pp metals = priority pollutant metals.

<sup>c</sup> EC = Environmental Canada, GC methods with Megabore Column or Purgen and trap.

#### SYSTEM THREE - UV-OXIDATION

UV-Oxidation tests will be performed in the immediate future .



REVERSE OSMOSIS (RO) TREATMENT SYSTEM

FIGURE 9.



## RECOMMENDATIONS

A higher PAC loading (such as 10 g/L) should be explored in combination with MF on the waste as this may create a higher quality filtrate. In addition, this would have the effect of increasing the filtrate flow rates from a phenomenon known as the "tubular pinch effect". Tubular pinch effect is the flow regime set up in tubes where the bulk flow of liquid in the center of the tube is in a turbulent regime and the liquid on the sides of the tube is laminar. EC claims this effect reduced fouling.

Further work should be performed with the PAC/MF concentrate to eliminate all concentrate liquids by processing with a small MF cartridge. This cartridge is disposable and contains a pleated membrane of a pore size of 0.2 microns. It may be possible to achieve this same quality of filtrate with the cartridge as it is with the larger tubular MF membranes. In addition, because these cartridges are very portable, disposable, and operate under crossflow conditions (and therefore do not foul too quickly as do conventional filter cartridges with slurries), it may be feasible to use a bank of these cartridges to pretreat the waste prior to RO treatment.

Further work should be done with the RO permeate: concentrate ratio controlled at 4:1 or 8:1. The permeate: concentrate ratio is the ratio of the flows of permeate and concentrate leaving the system and does not include the recycle flow rate in the recycle loop. Since one of the control valves on the RO unit would not seat properly, it was impossible to try RO at different ratios. It is important to determine the performance of the system under these conditions as this may reduce the duration required to treat the waste. It could reduce downtime since the membranes may foul less rapidly.

Although this testing was conducted on a pilot plant scale, field tests should be conducted as well to determine how the system(s) would perform under actual treatment conditions, for longer durations and at higher concentrations of the leachate. Additional field tests are necessary to explore the effect of concentration ratio on permeate flux through the membrane to assist in system design and to observe the effect of the leachate on membrane fouling to assist in process design. Furthermore, field tests will explore the delicate art of membrane cleaning after long filtration runs by devising a cleaning regime and exploring different mixes of cleaning agents.

TABLE 6. ANALYTICAL RESULTS, VOLATILE ORGANICS

VOLATILE ORGANICS	S9	S9	S5	S5 (2)	S1 S7	S1 PAC/NF	S7 NO PERM.	S4	S4	S8	S8
	DETECTION LIMIT (ug/l)	LANDFILL LEACHATE (ug/l)	DETECTION LIMIT (ug/l)	LANDFILL LEACHATE (ug/l)	DETECTION LIMIT (ug/l)	PERMEATE AFTER CONC. (ug/l)	AFTER CONC. 1st PASS (ug/l)	DETECTION LIMIT (ug/l)	PERMEATE AFTER CONC. (ug/l)	DETECTION LIMIT (ug/l)	AFTER CONC. 2nd PASS (ug/l)
Benzene	-	920J	500	1000	250	68J	ND	100	ND	5.0	24
Bromodichloroethane	1250	ND	500	ND	250	ND	ND	100	ND	5.0	ND
Bromoform	1250	ND	500	ND	250	ND	ND	100	ND	5.0	ND
Bromoethane	2500	ND	1000	ND	500	ND	ND	200	ND	10	ND
Carbon Tetrachloride	1250	ND	500	ND	250	ND	ND	100	ND	5.0	ND
Chlorobenzene	-	790J	500	750	250	ND	ND	100	ND	5.0	3.2J
Chloroethane	2500	ND	1000	ND	500	ND	ND	200	ND	10	ND
2-Chloroethylvinyl Ether	2500	ND	1000	ND	500	ND	ND	200	ND	10	ND
Chloroform	1250	ND	500	ND	250	ND	ND	100	ND	5.0	4.1J
Chloroethane	2500	ND	1000	ND	500	ND	ND	200	ND	10	1.6J
Dibromochloroethane	1250	ND	500	ND	250	ND	ND	100	ND	5.0	ND
1,1-Dichloroethane	-	480J	500	550	250	168J	ND	100	ND	5.0	23
1,2-Dichloroethane	-	960J	500	1100	250	374	170J	100	ND	5.0	179
1,1-Dichloroethane	1250	ND	500	ND	250	ND	ND	100	ND	5.0	3.2J
trans-1,2-Dichloroethane	-	13300	500	17400	250	3630	3760	100	100	5.0	4850
1,2-Dichloropropane	1250	ND	500	ND	250	ND	ND	100	ND	5.0	ND
cis-1,3-Dichloropropane	1250	ND	500	ND	250	ND	ND	100	ND	5.0	ND
trans-1,3-Dichloropropane	1250	ND	500	ND	250	ND	ND	100	ND	5.0	ND
Ethyl Benzene	-	4100	500	3400	250	ND	ND	100	ND	5.0	6.6
Methylene Chloride	-	25900	500	25700	250	8720	10000	100	1100	5.0	18300
1,1,2,2-Tetrachloroethane	1250	ND	500	ND	250	ND	ND	100	ND	5.0	ND
Tetrachloroethane	-	470J	500	170J	250	ND	ND	100	ND	5.0	ND
Toluene	-	6300	500	3910	250	75J	65J	100	ND	5.0	61.3
1,1,1-Trichloroethane	1250	ND	500	250J	250	ND	ND	100	ND	5.0	3.6J
1,1,2-Trichloroethane	1250	ND	500	ND	250	ND	ND	100	ND	5.0	ND
Trichloroethane	1250	ND	500	100J	250	ND	ND	100	ND	5.0	3.5J
Trichlorofluoroethane	1250	ND	500	ND	250	ND	ND	100	ND	5.0	ND
Vinyl Chloride	-	1300J	1000	1800	500	570	770	200	ND	10	674
Xylenes (Total)	-	10000	500	6600	250	ND	ND	100	ND	5.0	13
(tentatively identified compounds)											
Acetone	-	400	500	-	-	570	570	-	89	-	-
Trichlorofluoroethane (Freon 113)	-	420	500	-	-	-	-	-	-	-	-
Isopropanol	-	420	500	-	-	130000	-	-	3900	-	-
4-Methyl-2-Pentanone (MIBK)	-	-	-	750	-	-	-	-	-	-	-

ug/l denotes ppb

ug/l denotes ppm

TABLE 7. ANALYTICAL RESULTS, BASE NEUTRAL EXTRACTABLES

BASE NEUTRAL EXTRACTABLES	90	90	95	95 (2)	94	97	98	91	94	97	98	91	94	97	98	91	94	97	98	91	94	97	98	91	94	97	98	91	94	97	98	91	94	97	98	
	DETECTION	LANDFILL	DETECTION	LANDFILL	DETECTION	PERMEATE	PERMEATE	PERMEATE	PERMEATE	PERMEATE	PERMEATE	PERMEATE	PERMEATE	PERMEATE	PERMEATE	PERMEATE	PERMEATE	PERMEATE	PERMEATE	PERMEATE	PERMEATE	PERMEATE	PERMEATE	PERMEATE	PERMEATE	PERMEATE	PERMEATE	PERMEATE	PERMEATE	PERMEATE	PERMEATE	PERMEATE	PERMEATE	PERMEATE	PERMEATE	
	LIMIT	LEACHATE	LIMIT	LEACHATE	LIMIT	AFTER CONC.	AFTER CONC.	AFTER CONC.	AFTER CONC.	AFTER CONC.	AFTER CONC.	AFTER CONC.	AFTER CONC.	AFTER CONC.	AFTER CONC.	AFTER CONC.	AFTER CONC.	AFTER CONC.	AFTER CONC.	AFTER CONC.	AFTER CONC.	AFTER CONC.	AFTER CONC.	AFTER CONC.	AFTER CONC.	AFTER CONC.	AFTER CONC.	AFTER CONC.	AFTER CONC.	AFTER CONC.	AFTER CONC.	AFTER CONC.	AFTER CONC.	AFTER CONC.	AFTER CONC.	AFTER CONC.
(ug/l)	(ug/l)	(ug/l)	(ug/l)	(ug/l)	(ug/l)	(ug/l)	(ug/l)	(ug/l)	(ug/l)	(ug/l)	(ug/l)	(ug/l)	(ug/l)	(ug/l)	(ug/l)	(ug/l)	(ug/l)	(ug/l)	(ug/l)	(ug/l)	(ug/l)	(ug/l)	(ug/l)	(ug/l)	(ug/l)	(ug/l)	(ug/l)	(ug/l)	(ug/l)	(ug/l)	(ug/l)	(ug/l)	(ug/l)	(ug/l)	(ug/l)	
1,3-Dichlorobenzene	20	ND	100	ND	10	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
1,4-Dichlorobenzene	20	ND	100	ND	10	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Hexachloroethane	20	ND	100	ND	10	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Bis (2-Chloroethyl) Ether	-	31	100	34.1	10	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,2-Dichlorobenzene	-	127	100	81.1	10	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Bis (2-Chloroisopropyl) Ether	20	ND	100	ND	10	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
N-Nitrosodi-n-Propylamine	20	ND	100	ND	10	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Nitrobenzene	20	ND	100	ND	10	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Hexachlorobutadiene	20	ND	100	ND	10	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,2,4-Trichlorobenzene	20	ND	100	ND	10	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Isoborane	-	28	100	28.1	10	2.1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Naphthalene	-	25	100	28.1	10	7.2	6.5	3.5	4.5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Bis (2-Chloroethoxy) ethane	20	ND	100	ND	10	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Hexachlorocyclopentadiene	20	ND	100	ND	10	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2-Chloronaphthalene	20	ND	100	ND	10	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Acenaphthylene	20	ND	100	ND	10	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Acenaphthene	20	ND	100	ND	10	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Diethyl Phthalate	20	ND	100	ND	10	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2,6-Dinitrotoluene	20	ND	100	ND	10	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Fluorene	20	ND	100	ND	10	8.3	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
4-Chlorophenyl Phenyl Ether	20	ND	100	ND	10	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2,4-Dinitrotoluene	20	ND	100	ND	10	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Diethyl Phthalate	-	3.1	100	ND	10	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
N-Nitrosodiphenylamine	-	2.1	100	ND	10	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Hexachlorobenzene	20	ND	100	ND	10	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
4-Bromophenyl phenyl Ether	20	ND	100	ND	10	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Phenanthrene	20	ND	100	ND	10	8.4	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Anthracene	20	ND	100	ND	10	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Di-n-Butyl Phthalate	-	3.1	100	ND	10	ND	4.8	6.5	5.6	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

ug/l denotes ppb

ug/ml denotes ppm

TABLE 8. ANALYTICAL RESULTS, BASE NEUTRAL AND ACID EXTRACTABLES

	S0	S0	S5	S5 (2)	S1	S4	S7	S8	S1	PAC/NF	S4	PAC/NF/RO1	S7	RO PERM.	S8	RO PERM.
BASE NEUTRAL EXTRACTABLES	DETECTION	LANDFILL	DETECTION	LANDFILL	DETECTION	PERMEATE	PERMEATE	AFTER CONC.	AFTER CONC.	1st PASS	2nd PASS					
	(ug/l)	(ug/l)	(ug/l)	(ug/l)	(ug/l)	(ug/l)	(ug/l)	(ug/l)	(ug/l)	(ug/l)	(ug/l)	(ug/l)	(ug/l)	(ug/l)	(ug/l)	(ug/l)
Fluoranthene	20	ND	100	ND	10	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Pyrene	20	ND	100	ND	10	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Benzidine	20	ND	100	ND	10	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Butyl Benzyl Phthalate	20	ND	100	ND	10	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Bis (2-Ethylhexyl) Phthalate	-	15.8	100	85.8	10	168	24.48	128	25.48							
Chrysene	20	ND	100	ND	10	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Benzo(a)Anthracene	20	ND	100	ND	10	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,3'-Dichlorobenzidine	20	ND	100	ND	10	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Di-n-Octyl Phthalate	-	77	100	ND	10	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Benzo(b)Fluoranthene	20	ND	100	ND	10	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Benzo(k)Fluoranthene	20	ND	100	ND	10	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Benzo(a)Pyrene	20	ND	100	ND	10	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Indeno(1,2,3-c,d)Pyrene	20	ND	100	ND	10	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Di benzo (a,h)Anthracene	20	ND	100	ND	10	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Benzo (ghi)Perylene	20	ND	100	ND	10	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
N-Nitrosodimethylamine	20	ND	100	ND	10	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
ACID EXTRACTABLES																
2-Chlorophenol	20	ND	100	ND	10	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2-Nitrophenol	20	ND	100	ND	10	3.0	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Phenol	-	935	100	366	10	ND	5.0	73.8	124							
2,4-Dimethylphenol	-	345	100	63	10	ND	ND	2	3.5							
2,4-Dichlorophenol	20	ND	100	ND	10	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2,4,6-Trichlorophenol	20	ND	100	ND	10	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
4-Chloro-3-Methylphenol	20	ND	100	ND	10	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2,4-Dinitrophenol	100	ND	500	ND	50	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2-Methyl-4,6-dinitrophenol	20	ND	100	ND	10	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Pentachlorophenol	100	ND	500	ND	50	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
4-Nitrophenol	20	ND	100	ND	10	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

ug/l denotes ppb

ug/sl denotes ppm

TABLE 9. ANALYTICAL RESULTS, BASE NEUTRAL AND ACID EXTRACTABLES

BASE NEUTRAL & ACID EXTRACTABLES (tentatively identified compounds)	98	95 (2)	91 PAC/MF	194 PAC/MF/RO197	RO PERM.	198 RO PERM.
	LANDFILL LEACHATE (ug/l)	LANDFILL LEACHATE (ug/l)	PERMEATE AFTER CONC. (ug/l)	PERMEATE AFTER CONC. (ug/l)	AFTER CONC. 1st PASS (ug/l)	AFTER CONC. 2nd PASS (ug/l)
4-Methyl-2-Pentanone	2600	3500	720	-	18	28
Toluene	3400	3400	-	-	-	-
N,N-Dimethyl Formamide	420	470	800	27	19	6.0
Chlorobenzene	440	690	-	-	-	-
Ethyl Benzene	2600	2500	-	-	-	-
Xylene Isomer	3400	3900	-	-	4.0	6.0
Xylene Isomer	350	1300	-	-	-	-
Benzenamine	1100	1400	-	-	110	130
Hexanoic Acid	1500	-	-	-	-	-
N-Methyl-Benzenamine	4600	7200	-	-	170	170
N,N-Dimethyl-Benzenamine	6700	5000	32	-	18	-
Dimethyl Phenol Isomer	630	-	-	-	-	-
Ethyl Phenol Isomer	370	-	-	-	-	-
Trimethyl Phenol Isomer	110	-	-	-	-	-
N-Methyl-N-Phenyl Formamide	360	-	-	-	-	-
Dimethylethyl Phenol Isomer	320	240	-	-	-	-
N-Cyclohexyl Cyclohexamine	2100	-	-	-	-	-
Butanoic Acid	-	-	3000	38	78	100
Pentanoic Acid	-	-	120	-	-	-
1-Methyl-2-Pyrrolidinone	-	1400	1100	-	4.0	6.0
Butanoic Acid Anhydride	-	-	-	150	-	-
Phenoxyethyl Oxirane	-	-	-	7	4.0	-
Bicyclo[4.2.0]Octa-1,3,5-Triene	-	300	-	-	-	-
4-Methyl Phenol	-	180	-	-	46	79
2-Ethyl-Hexanoic Acid	-	4400	-	-	-	-
Benzoic Acid	-	7600	-	-	15	7.0
Tetramethyl Butyl Phenol Isomer	-	110	-	-	-	-
Methyl Phenol Isomer	-	-	-	-	9	16
3-Ethyl Phenol	-	-	-	-	-	21



## ANALYTICAL

### RESULTS

Tables 6 through 10 summarizes the analytical data of the remedial investigation and the Phase I engineering study. The detailed analyses from Envirotech of Edison, NJ, the subcontract laboratory, are placed in Appendix 1. In addition, the full report containing chromatograms, QA/QC information, and miscellaneous details is maintained in the REAC archives for inspection.

## DISCUSSION OF RESULTS

Reverse osmosis with or without powdered activated carbon and microfiltration pretreatment was very successful in removing organic and inorganic contaminants from the PAS landfill leachate. The effectiveness of removal was calculated as the difference between the original concentration of a constituent contaminant in the untreated leachate and the residual constituent in the permeate divided by the original concentration. Tables 11, 12, and 13 show that the PAC/MF/RO and the RO systems removed between 90 to 100 percent of most contaminants in the untreated leachate. If necessary, the contaminants unaffected by treatment can be eliminated by an inexpensive polish step, if necessary. Overall, the preliminary evaluation of the application of these technologies at the PAS site indicates a technically feasible treatment.



TABLE 11. TREATMENT EFFICIENCY OF VOLATILE ORGANICS

VOLATILE ORGANICS	Untreated	PAC/MF/RO		REVERSE OSMOSIS (RO)	
	Sample	TREATMENT	TREATMENT	TREATMENT	TREATMENT
	SS (2)	S1 PAC/MF	S4 PAC/MF/RO	S7 RO PERM.	S8 RO PERM.
	LANDFILL	PERMEATE	PERMEATE	AFTER CONC.	AFTER CONC.
	LEACHATE	AFTER CONC.	AFTER CONC.	1st PASS	2nd PASS
	(ug/l)	(% Reject)	(% Reject)	(% Reject)	(% Reject)
Benzene	1000	94.1	100	100	97.6
Chlorobenzene	760	100	100	100	99.6
1,1-Dichloroethane	560	71.4	100	100	95.9
1,2-Dichloroethane	1100	66	100	84.5	83.7
trans-1,2-Dichloroethene	17400	79.1	99.4	78.4	76.7
Ethyl Benzene	3400	100	100	100	99.8
Methylene Chloride	25700	66.1	95.7	68.8	59.9
Tetrachloroethene	170	100	100	100	100
Toluene	5910	98.7	100	98.9	99.8
1,1,1-Trichloroethane	250	100	100	100	98.6
Trichloroethene	180	100	100	100	98.8
Vinyl Chloride	1800	68.3	100	56.8	62.6
Xylenes (Total)	6600	100	100	100	99.8
(tentatively identified compounds)					
Acetone	-	0*	81.4*	0*	-

ug/l denotes ppb

ug/ml denotes ppm

\* Based on Acetone concentration previously found in Sample 0; use values for qualitative purposes only.

TABLE 12. TREATMENT EFFICIENCY OF BASE NEUTRAL AND ACID EXTRACTABLES

	Untreated	PAC/MF/RO		REVERSE OSMOSIS (RO)	
	Sample	TREATMENT		TREATMENT	
	SS (2)	S1 PAC/MF	IS4 PAC/MF/RO	IS7 RO PERM.	IS8 RO PERM.
BASE NEUTRAL EXTRACTABLES	LANDFILL	PERMEATE	PERMEATE	AFTER CONC.	AFTER CONC.
	LEACHATE	AFTER CONC.	AFTER CONC.	1st PASS	2nd PASS
	(ug/l)	(% Reject)	(% Reject)	(% Reject)	(% Reject)
Bis (2-Chloroethyl) Ether	34J	100	100	100	100
1,2-Dichlorobenzene	81J	100	100	100	100
Isophorone	20J	90J	100	100	100
Naphthalene	20J	64J	67.5J	82.5J	77.5J
Bis (2-Ethylhexyl) Phthalate	85J	81.2	71.3	85.9	71.2B
ACID EXTRACTABLES					
Phenol	366	100	98.6J	79.8	66.1
2,4-Dimethylphenol	63J	100	100	96.8J	99.4
BASE NEUTRAL & ACID EXTRACTABLES (tentatively identified compounds)					
4-Methyl-2-Pentanone	3500	79.4	-	99.5	99.2
N,N-Dimethyl Formamide	470	0	94.2	96.0	98.7
Xylene Isomer	3900	-	-	99.9	99.8
Benzenamine	1400	-	-	92.1	98.7
N-Methyl-Benzenamine	7200	-	-	97.6	97.6
N,N-Dimethyl-Benzenamine	5800	99.1	-	99.7	-
1-Methyl-2-Pyrrolidinone	1400	21.4	-	99.7	99.6
4-Methyl Phenol	180	-	-	74.4	56.1
Benzoic Acid	7600	-	-	99.8	99.9

TABLE 13. TREATMENT EFFICIENCY OF METALS AND WET CHEMISTRY

Untreated Sample	POWERED ACTIVATED WITH MICROFILTRATION and REVERSE OSMOSIS TREATMENT (PAC/NF/RO)	REVERSE OSMOSIS TREATMENT
SS (2)	S1 PAC/NF   S1 PAC/NF   S1 PAC/NF   S1 PAC/NF   S6 RO PERM   S6 RO PERM   S7 RO PERM   S8 RO PERM   S9, RO	100   100   100   100   100   100   100   100   100
LANDFILL LEPERATE	AFTER PERMATE   AFTER PERMATE   AFTER RECYC   AFTER RECYC   AFTER CONC.   AFTER CONC.   1st PASS   2nd PASS   1st PASS	100   100   100   100   100   100   100   100   100
LEPERATE (ug/l)	RECYCLE   RECYCLE   RECYCLE   RECYCLE   BEFORE CONC.   BEFORE CONC.   (X Reject)   (X Reject)   (X Concen.)	100   100   100   100   100   100   99.5   98.9   425
Antimony	3.9   0.05   23.1   100   100   100   100   100   100	100   100   100   100   100   100   100   100   446
Arsenic	32.5   71.4   69.5   100   100   100   100   100   100	100   100   100   100   100   100   100   100   368
Calcium	60,000   30.7   34.4   99.9   99.8   99.8   99.8   99.8   99.8	100   100   100   100   100   100   100   100   425
Chromium	18.5   72.4   69.7   62.2   100   100   100   100   100	100   100   100   100   100   100   100   100   283
Copper	39   23.1   0   100   100   100   100   100   100	100   100   100   100   100   100   100   100   1355
Iron	99700   68.7   95.6   100   100   100   100   100   100	100   100   100   100   100   100   100   100   338
Lead	16   100   100   100   100   100   100   100   100	100   100   100   100   100   100   100   100   866
Nickel	2570   32.3   29.2   100   100   100   100   100   100	100   100   100   100   100   100   100   100   465
Silver	13   0.08   100   100   100   100   100   100   100	100   100   100   100   100   100   100   100   323
Thallium	2.3   100   100   100   100   100   100   100   100	100   100   100   100   100   100   100   100   NO
Zinc	2428   68   68   68   68   68   68   68   68	100   100   100   100   100   100   100   100   30000
WET CHEMISTRY (mg/l)		
TSS	23   100   100   100   100   100   100   100   100	100   100   100   100   100   100   100   100   -
TDS	4900   31.3   97.1   97.1   97.1   97.1   97.1   97.1   97.1	100   100   100   100   100   100   100   100   -
TOC	580   0   0   0   0   0   0   0   0	100   100   100   100   100   100   100   100   -
COO	2100   0   0   0   0   0   0   0   0	100   100   100   100   100   100   100   100   -
SO4- (Sulfate)	6   0   0   0   0   0   0   0   0	100   100   100   100   100   100   100   100   -

## FUTURE PLANS

### TECHNICAL EVALUATION

All information generated from the pilot-scale treatability studies performed at Environment Canada will be evaluated to determine the technical viability of each treatment alternative examined. Factors considered will include rejection rates, permeate and retentate generation rates, acceptability of permeate for discharge or reinjection, constraints on retentate disposal, etc. For those technologies deemed technically viable, ERT will perform economic feasibility study. For those deemed technically inappropriate, ERT will discontinue the evaluation effort.

## ECONOMIC FEASIBILITY

For each treatment technology where the pilot-scale studies successfully demonstrate the technical application, a detailed cost analysis will be performed. The purpose of this evaluation is to establish that a treatment option is economically feasible before conducting a full-scale, on-site treatability study. Factors considered in this evaluation include disposal costs for concentrated wastes versus dilute wastes, capital costs of treatment units, utility costs, manpower requirements, equipment maintenance, sampling costs, chemical costs, etc. The on-site treatability study will be performed if, and only if, a treatment technology is both technically and economically acceptable.

MONITORING WELL INVESTIGATION  
AT POLLUTION ABATEMENT SERVICES,  
OSWEGO, NEW YORK

## INTRODUCTION

To date, REAC has completed a detailed investigation of the groundwater monitoring wells at the Pollution Abatement Services (PAS) site. The investigation consisted of three main phases. The first phase involved an initial site survey and the sampling of selected wells on and off the site. The work was completed between 22 November and 25 November 1987. The second phase, from 4 January to 9 January 1988, consisted of a down-hole camera investigation and the execution of bail tests at six of the 18 selected wells. During the third phase, from 26 January to 30 January 1988, the remaining 12 wells were investigated and bail tested. The following is a summary of this work with recommendations for additional work needed at the site.

## FIELD INVESTIGATIONS

Figure 10 is a detailed map of the PAS site showing the configuration of the slurry wall, the position of the chain link fence surrounding the property, and the locations of the monitoring wells and the leachate pumping wells. There are several main groups of wells at the site. Wells labeled "LC" are the leachate collection wells. The monitoring wells labeled "SWW" were installed by URS Company (Hacker, 1987) after the emplacement of the slurry wall. They were installed for the purpose of monitoring the performance of the leachate collection system by comparing the water chemistry on opposite sides of the slurry wall. The outer wells are also used to monitor the slurry wall integrity. Wells labeled "MW" were installed by Woodward-Clyde Consultants (Versar, 1987). This group consists of an upgradient couplet (MW11A and MW11B), two single wells (MW9 and MW10), and a downgradient couplet (MW7 and MW7B). There is also a triplet labeled "1M" at the northwest corner of the site, a triplet labeled "2" near the northeast corner of the site, and a couplet labeled "NP" near the northeast corner of the site. There is one isolated well labeled "IP" near the northeast corner.

Table 14 is a summary of the data collected during this investigation. Water samples were collected during the first phase of this investigation. Versar (1987) reported significant contamination in SWW4 and SWW6. Our chemical data indicates only moderate contamination in SWW4 (total VOA = 183 ug/l, total BNA = 24 ug/l), however, matrix interference may have resulted in low values for this well (Chang, 1988). SWW6 is definitely contaminated. The total for VOAs is 2974 ug/l and the total for BNAs is 1330 ug/l. The primary volatile organic compounds are methylene chloride, chloroform, bromochloromethane, benzene, and toluene. The most prominent base/neutral/acid extractable compounds are 2,4 dimethylphenol and 1,2 dichlorobenzene. The concentrations of these chemicals in this well indicate that the slurry wall has been breached in this area.

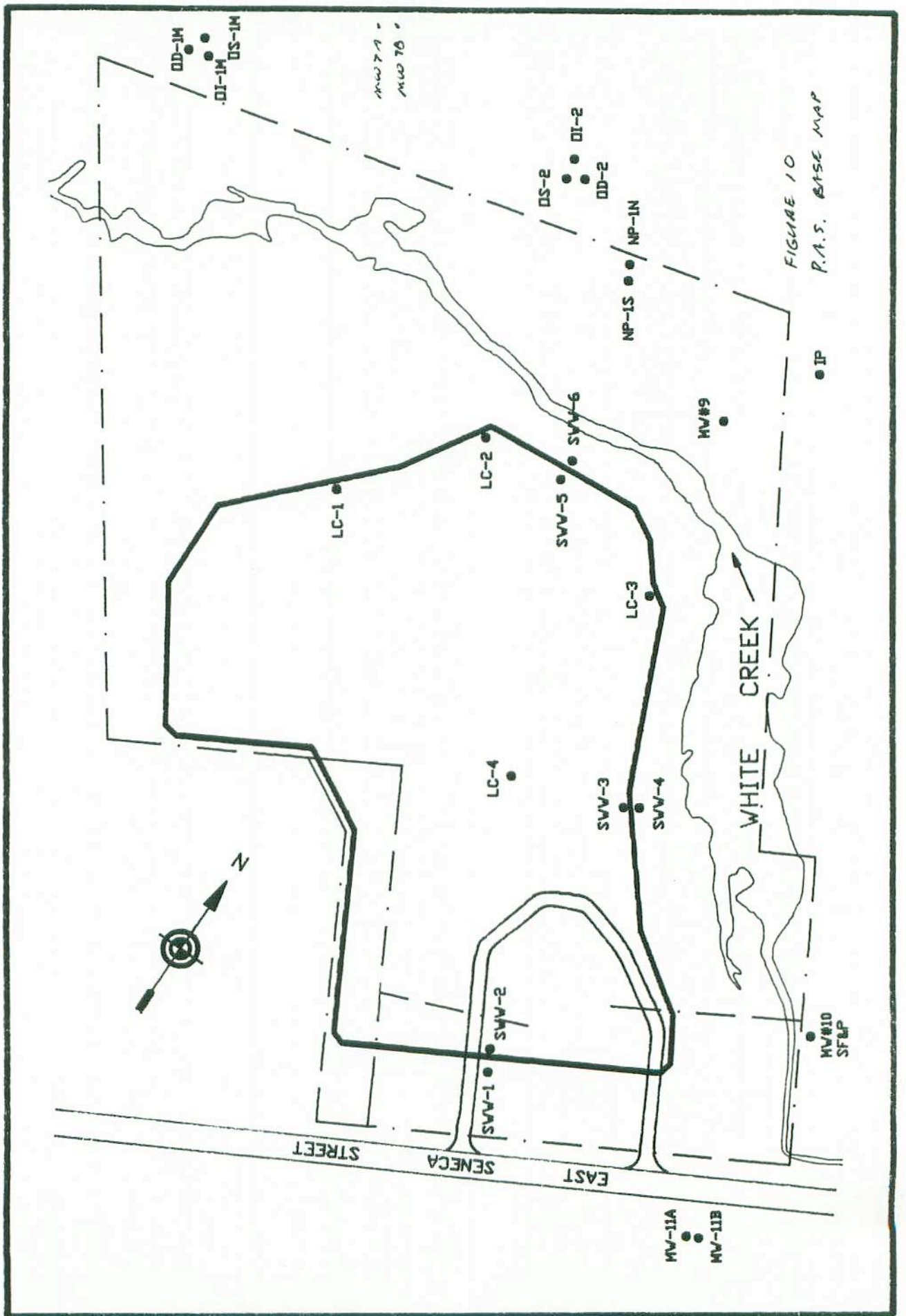


FIGURE 10  
P.A.S. BASE MAP

Table 14

WELL #	CONDITION	DIAMETER (in)	DEPTH (ft)	SCREEN (ft)	CHEMISTRY TOTALS		WATER TABLE ELEVATIONS
					VOA (ug/L)	BNA <del>(ug/L)</del> (ug/L)	
MW11B	Kinked, rusty cracked, scale	3	41.3	31.4-41.3' Open Hole	40.3	0	---
MW11A	Corroded, needs flushing	3	10.8	6.8-10.8'	172	0	282.3
SWW1	Clean Well	3	19.7	9.2-19.7'	-	-	278.1
SWW2	Surface scum clean screen	3	17.6	9.1-17.6	-	-	270.9
SWW3	Needs flushing	3	19.6	10.6-19.6	-	-	266.5
SWW4	Clean screen good condition	3	25.4	15.4-25.4	183	24	266.4
SWW5	Corroded casing clean screen	3	21.4	11.4-21.4	-	-	264.3
SWW6	Clean screen good condition	3	17.0	7.3-17.0	2974	1330	264.0
IP	Good condition	4	52.6	Open Hole 18.1-52.6	344	0	267.8
OS-1M	Good condition	3	14.7	5.7-14.7	32	0	259.8
OI-1M	Needs flushing	3	27.2	22.2-27.2	4	0	256.8
OD-1M	Casing encrusted rock in hole	4.1	42.6	Open Hole 34.6-Bottom	62	0	258.0
MW7A	Needs flushing or rebuilding	3	18.6	14.9-18.6	10.2	0	-
MW7B	Needs flushing	3	25.4	20.4-25.4	7.3	33.1	-
OS-2	Good condition	3	17.7	6.9-17.7	5.8	0	261.1
OI-2	Needs some flushing	3	21.1	15.1-21.1	6	0	260.0
OD-2	Good condition	4	73.4	Open Hole 28.1-73.4	0	0	254.0
MW10	Need flushing	3	13.43	8.3-13.43	13.1	0	272.0



The condition of the monitoring wells was investigated during the second and third phases of this project. A subcontractor (Geoprobe, Inc.) was hired to examine the wells with a down-hole camera. The condition of the well was examined with a video monitor and was recorded on videotape. The videotape logs are shown in Appendix 2. The "MW" wells were generally found to be in poor condition. MW11B is severely rusted and the casing is bent. MW11A is corroded and needs flushing. MW7A and MW7B are corroded to the extent that the integrity of the chemical data from these wells is dubious. Wells SWW3, OI-1M, OI-2, and MW10 are all in fair condition except for the fact their screens are clogged with sediment. This problem could be easily solved by flushing the wells.

Bail tests were performed on all the wells investigated at this site. A pressure transducer was connected to a digital data recorder and lowered to a depth of 10 to 15 ft below the surface of the water. The base level was recorded at that point. A bailer was then lowered into the well and a second base level was recorded. The bailer was then swiftly removed from the well and the water recovery was monitored and recorded on magnetic tape. The value of the hydraulic conductivity (k) was determined using the Hvorslev (1951) method. The recovery data is graphically displayed in Appendix 3. Table 15 shows the results for several of the wells at the site. SWW6 shows a very low flow velocity (0.0095 ft/day). Assuming that the well is about 5 ft from the slurry wall and that the breach in the wall is very close to SWW6, it would take the contaminants approximately 1.5 years to reach the well. The high flow velocity value for OD2 is a manifestation of fracture flow in the bedrocks.

#### CONCLUSIONS

Several wells at the PAS site need complete replacement. MW11A, MW11B, MW7A, and MW7B are so highly corroded that the chemistry of the groundwater samples may be significantly influenced by the poor conditions of the well casings. The video logs indicate that the screens in SWW3, OI-1M, OI-2, and MW10 are substantially clogged. These wells need to be flushed before the aquifer parameters can be accurately determined. Figure 1 shows that there is a lack of monitoring wells just outside the slurry wall on the northwest side of the site. Additional wells should be installed in this area to test the integrity of the slurry wall.

Table 15  
VELOCITY CALCULATIONS

$$v = [k (dh/dl)] / (7.48 n)$$

dh/dl = hydraulic gradient (ft/ft)

n = porosity

k = hydraulic conductivity (gpd/ft<sup>2</sup>)

7.48 = conversion factor (gpd/ft<sup>2</sup> -- ft/day)

WELL	dh/dl	n	k (gpd/ft <sup>2</sup> )	v (ft/day)
SWW1	0.023	0.46	42.13	0.28
SWW6	0.023	0.46	1.42	0.0095
MW7B	0.023	0.46	34.7	0.23
OS2	0.023	0.46	14.2	0.95
OD2	0.023	0.46	240	1.60

## REFERENCES

Chang, J., 1988. Analytical Report, Pollution Abatement Services Site, Oswego, NY. EPA Work Assignment #0-60.

Hacker, G., 1987. Draft Letter Report, Sampling and Analysis, Pollution Abatement Services Site. EPA Work Assignment #212.



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TO: Tom Kady, U.S. Environmental Protection Agency,  
Environmental Response Team

FROM: Robert Evangelista, REAC

SUBJECT: PRELIMINARY ECONOMIC ANALYSIS FOR THE PROPOSED TREATMENT SYSTEMS  
AT THE POLLUTION ABATEMENT SERVICES SITE, OSWEGO, NY

DATE: 17 May 1988

cc: File 3347-01-01-1083

This preliminary economic analysis was performed by the Response Engineering and Analytical Contractor (REAC) for the U.S. Environmental Protection Agency's Environmental Response Team (ERT) as a part of Work Assignment 0-83. This work assignment is exploring the use of innovative on-site treatment technology to reduce off-site treatment cost at the Pollution Abatement Services site (PAS) in Oswego, NY. PAS has been treating approximately 65,000 gallons of landfill leachate per month (780,000 gallons/year) at an off-site facility. According to the former U.S. EPA On-Scene Coordinator, Bret Hensley, the cost of treatment is \$0.31/gallon (approximately \$241,000/year). The overall objective of the project is to reduce treatment cost by exploring the selected appropriate technology - reverse osmosis. The objective of this preliminary economic analysis is to determine if additional on-site pilot efforts are warranted from an economic perspective.

Preliminary pilot tests at Environment Canada's Ottawa, Ontario facility in February 1988 demonstrated the technical feasibility of reverse osmosis and powdered activated carbon/microfiltration/reverse osmosis to reduce the amount waste transported and treated off-site. An on-site pilot test at PAS is necessary to explore the following items:

- o The technical feasibility of extended operation with the PAS leachate;
- o The maximum amount that the leachate can be concentrated (minimized);
- o The treatment process parameters necessary for system design.

This effort looked at eight treatment systems - 4 manually operated and 4 fully automated. Systems 1, 1-A, 2, and 2-A were evaluated. They are a 10 gallon per minute (GPM) reverse osmosis system, similar in design to

Environment Canada's mobile reverse osmosis systems, differ in materials of construction and level of automation with system 1 containing plastic hose, plumbing, and fittings and system 2 stainless steel. The "A" suffix denotes fully automated system. Environment Canada has nearly a decade of experience with this system. Systems 3 and 3-A are small pilot-scale reverse osmosis systems with a 2.5 GPM capacity (with a range of 0.8 to 5 GPM). Smaller systems were explored because the approximately 65,000 gallons of leachate treated each month off-site equates to approximately 1.5 GPM on an around-the-clock basis. Therefore, a continuously operated small system is a feasible option. Finally, Systems 4 and 4-A is a reverse osmosis unit with a powdered activated carbon/microfiltration pretreatment. Environment Canada is currently exploring this technology combination and recommended its inclusion in pilot tests.

This analysis comprises three sections: 1) a summary, 2) an economic estimate, and 3) calculations. The summary section allows an at-a-glance review of the economic estimates for all eight systems. The economic estimate gives a detailed breakdown of the operating and capital costs, an annual savings (or loss) versus off-site treatment, and the return on investment for the system. The calculations section gives the assumptions and shows the derivation of the numbers used in the economic estimate.

I recommend additional reverse osmosis pilot testing, on-site, to further explore the technical feasibility to concentrate leachate and to get a more accurate economic estimate of the treatment costs. Systems 1, 2, and 3 have the best return on investments ranging from 1.7 to 2.6 years. The return on investment of the fully automated versions of these systems (1-A, 2-A, and 3-A) is more than double the manual systems. Although an attractive option, the added automation may not be necessary to treat PAS leachate or any other aqueous CERCLA wastes. Systems 4 and 4-A provide no return on investment because the cost is greater than off-site treatment. However, EPA/ERT may consider doing additional pilot test with this technology combination to further its development.

CAPITAL EQUIPMENT ECONOMIC ESTIMATE

SUMMARY OF PRELIMINARY ECONOMIC ANALYSIS FOR THE PROPOSED TREATMENT SYSTEMS AT THE POLLUTION ABATEMENT SERVICES SITE, OSWEGO, NY

SYSTEM 1  
Mobile Reverse Osmosis with Hose Plumbing

Capacity: 10 GPM (approximate)  
Capital Cost: \$104,700  
Operating Cost: \$0.2423/gallon  
Annual Savings (loss): \$52,806  
Return on Investment: 2.0 years

SYSTEM 1-A  
Mobile Reverse Osmosis with Hose Plumbing and Full Automation

Capacity: 10 GPM (approximate)  
Capital Cost: \$309,700  
Operating Cost: \$0.2342/gallon  
Annual Savings (loss): \$59,116  
Return on Investment: 5.2 years

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SYSTEM 2  
Mobile Reverse Osmosis with Stainless Steel Plumbing

Capacity: 10 GPM  
Capital Cost: \$139,300  
Operating Cost: \$0.2415/gallon  
Annual Savings (loss): \$53,430  
Return on Investment: 2.6 years

SYSTEM 2-A  
Mobile Reverse Osmosis with Stainless Steel Plumbing and Full Automation

Capacity: 10 GPM  
Capital Cost: \$344,300  
Operating Cost: \$0.2331/gallon  
Annual Savings (loss): \$59,982  
Return on Investment: 5.7 years

---

SYSTEM 3  
Mobile Reverse Osmosis

Capacity: 2.5 GPM  
Capital Cost: \$59,600  
Operating Cost: \$0.2644/gallon  
Annual Savings (loss): \$35,568  
Return on Investment: 1.7 years

SYSTEM 3-A  
Mobile Reverse Osmosis with Full Automation

Capacity: 2.5 GPM  
Capital Cost: \$264,600  
Operating Cost: \$0.2169/gallon  
Annual Savings (loss): \$72,618  
Return on Investment: 3.6 years

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SYSTEM 4  
Mobile Powdered Activated Carbon/  
Microfiltration and Reverse Osmosis

Capacity: 10 GPM  
Capital Cost: \$183,400  
Operating Cost: \$0.3148/gallon  
Annual Savings (loss): (\$3,744)  
Return on Investment: -----

SYSTEM 4-A  
Mobile Powdered Activated Carbon/  
Microfiltration and Reverse Osmosis  
with Full Automation

Capacity: 10 GPM  
Capital Cost: \$488,400  
Operating Cost: \$0.3283/gallon  
Annual Savings (loss): (\$14,274)  
Return on Investment: -----

SYSTEM 1. MOBILE REVERSE OSMOSIS  
 (with hose plumbing)  
 Capacity = 10 GPM (approximate)

OPERATING COST

<u>Items</u>	<u>Cost Per Gallon Treated</u>	
Equipment Maintenance	\$0.0064	
Equipment Depreciation	0.0105	
Membrane Replacement	0.0108	
Electric & Chemicals	0.0133	
Labor	0.0400	
Sample Analysis	0.0128	
Concentrate Treatment	<u>0.1000</u>	
Subtotal	\$0.1938	
ERCS Cost	0.0194	
Contingency (15%)	<u>0.0291</u>	
Total Operating Cost		\$0.2423
Current Treatment Cost at Offsite Facility	\$0.3100	
Reverse Osmosis Treatment Cost	<u>0.2423</u>	
Savings per Gallon		\$0.0677
Annual Savings		\$52,806

CAPITAL COST

<u>Items</u>	<u>Cost</u>	
Mobile Reverse Osmosis System with hose plumbing	\$57,700	
Mobilization & Start-up	10,000	
Membranes	12,600	
Support Equipment	14,400	
Plumbing (installed)	5,000	
Electrical (installed)	<u>5,000</u>	
Total Capital Cost		\$104,700

RETURN ON INVESTMENT 2.0 years



SYSTEM 1-A. MOBILE REVERSE OSMOSIS  
 (with hose plumbing and full automation)  
 Capacity = 10 GPM (approximate)

OPERATING COST

<u>Items</u>	<u>Cost Per Gallon Treated</u>	
Equipment Maintenance	\$0.0128	
Equipment Depreciation	0.0362	
Membrane Replacement	0.0108	
Electric & Chemicals	0.0133	
Labor	-----	
Sample Analysis	0.0128	
Concentrate Treatment	<u>0.1000</u>	
Subtotal	\$0.1874	
ERCS Cost	0.0187	
Contingency (15%)	<u>0.0281</u>	
Total Operating Cost		\$0.2342
Current Treatment Cost at Offsite Facility	\$0.3100	
Reverse Osmosis Treatment Cost	<u>0.2342</u>	
Savings per Gallon		\$0.0758
Annual Savings		\$59,116

CAPITAL COST

<u>Items</u>	<u>Cost</u>	
Mobile Reverse Osmosis System with hose plumbing	\$ 57,700	
Reverse Osmosis Automation	200,000	
Mobilization & Start-up	15,000	
Membranes	12,600	
Support Equipment	14,400	
Plumbing (installed)	5,000	
Electrical (installed)	<u>5,000</u>	
Total Capital Cost		\$309,700
RETURN ON INVESTMENT		5.2 years

SYSTEM 2. MOBILE REVERSE OSMOSIS  
 (with stainless steel plumbing)  
 Capacity = 10 GPM (approximate)

OPERATING COST

<u>Items</u>	<u>Cost Per Gallon Treated</u>	
Equipment Maintenance	\$0.0013	
Equipment Depreciation	0.0150	
Membrane Replacement	0.0108	
Electric & Chemicals	0.0133	
Labor	0.0400	
Sample Analysis	0.0128	
Concentrate Treatment	<u>0.1000</u>	
Subtotal	\$0.1932	
ERCS Cost	0.0193	
Contingency (15%)	<u>0.0290</u>	
Total Operating Cost		\$0.2415
Current Treatment Cost at Offsite Facility	\$0.3100	
Reverse Osmosis Treatment Cost	<u>0.2415</u>	
Savings per Gallon		\$0.0685
Annual Savings		\$53,430

CAPITAL COST

<u>Items</u>	<u>Cost</u>	
Mobile Reverse Osmosis System with stainless steel plumbing	\$92,300	
Mobilization & Start-up	10,000	
Membranes	12,600	
Support Equipment	14,400	
Plumbing (installed)	5,000	
Electrical (installed)	<u>5,000</u>	
Total Capital Cost		\$139,300

RETURN ON INVESTMENT 2.6 years

SYSTEM 2-A. MOBILE REVERSE OSMOSIS  
 (with stainless steel plumbing and full automation)  
 Capacity = 10 GPM (approximate)

OPERATING COST

<u>Items</u>	<u>Cost Per Gallon Treated</u>	
Equipment Maintenance	\$0.0077	
Equipment Depreciation	0.0406	
Membrane Replacement	0.0108	
Electric & Chemicals	0.0133	
Labor	-----	
Sample Analysis	0.0192	
Concentrate Treatment	<u>0.1000</u>	
Subtotal	\$0.1916	
ERCS	0.0192	
Contingency (15%)	<u>0.0287</u>	
Total Operating Cost		\$0.2331
Current Treatment Cost at Off-Site Facility	\$0.3100	
Reverse Osmosis Treatment Cost	<u>0.2331</u>	
Savings Per Gallon		\$0.0769
Annual Savings		\$59,982

CAPITAL COST

<u>Items</u>	<u>Cost</u>	
Mobile Reverse Osmosis System With Stainless Steel Plumbing	\$ 92,300	
Reverse Osmosis Automation	200,000	
Mobilization & Start-up	15,000	
Membranes	12,600	
Support Equipment	14,400	
Plumbing (installed)	5,000	
Electrical (installed)	<u>5,000</u>	
Total Capital Cost		\$344,300

RETURN ON INVESTMENT 5.7 years

SYSTEM 3. MOBILE REVERSE OSMOSIS  
Capacity = 2.5 GPM (approximate)

OPERATING COST

<u>Items</u>	<u>Cost Per Gallon Treated</u>	
Equipment Maintenance	\$0.0013	
Equipment Depreciation	0.0060	
Membrane Replacement	0.0088	
Electric & Chemicals	0.0133	
Labor	0.0700	
Sample Analysis	0.0128	
Concentrate Treatment	<u>0.1000</u>	
Subtotal	\$0.2115	
ERCS	0.0212	
Contingency (15%)	<u>0.0317</u>	
Total Operating Cost		\$0.2644
Current Treatment Cost at Off-Site Facility	\$0.3100	
Reverse Osmosis Treatment Cost	<u>0.2644</u>	
Saving Per Gallon		\$0.0456
Annual Savings		\$35,568

CAPITAL COST

<u>Item</u>	<u>Cost</u>	
Mobile Reverse Osmosis System (used)	\$24,000	
Mobilization & Start-up	10,000	
Membranes	3,200	
Support Equipment	13,400	
Plumbing (installed)	4,000	
Electrical (installed)	<u>5,000</u>	
Total Capital Cost		\$59,600

RETURN ON INVESTMENT 1.7 years

SYSTEM 3-A. MOBILE REVERSE OSMOSIS  
Capacity = 2.5 GPM (approximate)

OPERATING COST

<u>Items</u>	<u>Cost Per Gallon Treated</u>	
Equipment Maintenance	\$0.0077	
Equipment Depreciation	0.0316	
Membrane Replacement	0.0081	
Electric & Chemicals	0.0133	
Labor	-----	
Sample Analysis	0.0128	
Concentrate Treatment	<u>\$0.1000</u>	
Subtotal	\$0.1735	
ERCS	0.0174	
Contingency (15%)	<u>0.0260</u>	
Total Operating Cost		\$0.2169
Current Treatment Cost at Off-Site Facility	\$0.3100	
Reverse Osmosis Treatment Cost	<u>0.2169</u>	
Saving Per Gallon		\$0.0931
Annual Savings		\$72,618

CAPITAL COST

<u>Item</u>	<u>Cost</u>	
Mobile Reverse Osmosis System (used)	\$ 24,000	
Reverse Osmosis Automation	200,000	
Mobilization & Start-up	15,000	
Membranes	3,200	
Support Equipment	13,400	
Plumbing (installed)	4,000	
Electrical (installed)	<u>5,000</u>	
Total Capital Cost		\$264,600

RETURN ON INVESTMENT 3.6 years

SYSTEM 4. MOBILE POWDERED ACTIVATED CARBON/MICROFILTRATION  
AND REVERSE OSMOSIS (RO with stainless steel plumbing)  
Capacity = 10 GPM

OPERATING COST

<u>Items</u>	<u>Cost Per Gallon Treated</u>	
Equipment Maintenance	\$0.0077	
Equipment Depreciation	0.0200	
Membrane Replacement	0.0121	
Electric & Chemicals	0.0200	
Powdered Activated Carbon	0.0392	
Labor	0.0400	
Sample Analysis	0.0128	
Carbon Treatment	NA	
Concentrate Treatment	<u>0.1000</u>	
Subtotal	\$0.2518	
ERCS	0.0252	
Contingency (15%)	<u>0.0378</u>	
Total Operating Cost		\$0.3148
Current Treatment Cost at Off-Site Facility	\$0.3100	
Reverse Osmosis Treatment Cost	<u>0.3148</u>	
Saving Per Gallon		(\$0.0048)
Annual Savings		(\$3,744)

CAPITAL COST

<u>Item</u>	<u>Cost</u>	
Mobile Reverse Osmosis System with Stainless Steel Plumbing	\$ 92,300	
Microfiltration	23,000	
Mobilization & Start-up	15,000	
Membranes	12,600	
Support Equipment	25,500	
Plumbing (installed)	7,500	
Electrical (installed)	<u>7,500</u>	
Total Capital Cost		\$183,400

RETURN ON INVESTMENT -----

SYSTEM 4-A. MOBILE POWDERED ACTIVATED CARBON/MICROFILTRATION  
AND REVERSE OSMOSIS (fully automated)  
Capacity = 10 GPM

OPERATING COST

<u>Items</u>	<u>Cost Per Gallon Treated</u>	
Equipment Maintenance	\$0.0205	
Equipment Depreciation	0.0580	
Membrane Replacement	0.0121	
Electric & Chemicals	0.0200	
Powdered Activated Carbon	0.0392	
Labor	-----	
Sample Analysis	0.0128	
Carbon Treatment	NA	
Concentrate Treatment	<u>0.1000</u>	
Subtotal	\$0.2626	
ERCS	0.0263	
Contingency (15%)	<u>0.0394</u>	
Total Operating Cost		\$0.3283
Current Treatment Cost at Off-Site Facility	\$0.3100	
Reverse Osmosis Treatment Cost	<u>0.3283</u>	
Saving Per Gallon		(\$0.0183)
Annual Savings		(\$14,274)

CAPITAL COST

<u>Item</u>	<u>Cost</u>	
Mobile Reverse Osmosis System with Stainless Steel Plumbing	\$ 92,300	
MF & RO Automation	300,000	
Microfiltration	23,000	
Mobilization & Start-up	20,000	
Membranes	12,600	
Support Equipment	25,500	
Plumbing (installed)	7,500	
Electrical (installed)	<u>7,500</u>	
Total Capital Cost		\$488,400

RETURN ON INVESTMENT -----

CALCULATIONS  
FOR  
ECONOMIC ESTIMATE



CALCULATIONS FOR SYSTEMS 1 AND 1-A

System	Item	Cost Calculations	Cost (based on 780,00 gal/yr)
1	Equipment	equipment = \$5,000/yr	\$0.0064/gal
1-A	maintenance <sup>a</sup>	[equipment] \$5,000/yr + [automation] \$5,000/yr = \$10,000/yr	\$0.0128/gal
1	Equipment	$(\$104,700 - 12,600 - 10,000)/10 = \$8,210/\text{yr}$	\$0.0105/gal
1-A	depreciation <sup>b</sup>	$(\$309,700 - 12,600 - 15,000)/10 = \$28,210/\text{yr}$	\$0.0362/gal
1	Membrane	(12 elements/1.5 yrs life) x (\$1050/element) = \$8,400/yr	\$0.0108/gal
1-A	replacement <sup>c</sup>	same as 1	\$0.0108/gal
1	Electric &	$(50/\text{day}) \times (4 \text{ days}/\text{wk}) \times (52 \text{ wks}/\text{yr}) = \$10,400/\text{yr}$	\$0.0133/gal
1-A	chemicals <sup>d</sup>	same as 1	
1	Labor <sup>e</sup>	$(\$150 \text{ salary}/8 \text{ hr day}) \times (4 \text{ days}/\text{wk}) \times (52 \text{ wks}/\text{yr}) = \$31,200/\text{yr}$	\$0.0400/gal
1-A		none	
1	Sample Analysis	(10 VOA, BNA, pp Metal analyses per year) x \$1,000/analysis = \$10,000/yr	\$0.0128/gal
1-A		same as 1	
1	Concentrate	78,000 gal/yr x \$1.00/gal = \$78,000/yr	\$0.100/gal
1-A	treatment <sup>f</sup>	same as 1	
1	Reverse Osmosis	unit = \$57,700	
1-A	Unit <sup>g</sup>	[unit] \$57,700 + [automation] \$200,000 = \$257,700	
1	Mobilization &	[unit] \$5,000 + [Murphy's Law] \$5,000 = \$10,000	
1-A	Start-up <sup>h</sup>	[unit] \$5,000 + [automation] \$5,000 + [Murphy's Law] \$5,000 = \$15,000	
1	Membrane <sup>g</sup>	(12 membrane elements/RO unit) x (\$1050/element) = \$12,600	
1-A		same as 1	
1	Support	2 vapor-phase carbon units for tank vents (Tigg, Inc.)	\$ 1,000
1-A	Equipment <sup>i</sup>	2 S.S., 55-gal tanks for chemicals (General Container)	\$ 1,000
		2 1000-gal tanks for feed and permeate (General Container)	\$ 3,000
		1 25' x 8' trailer (Gelco Space)	\$ 5,000
		Pumps (Veasey and Murphey)	\$ 4,400
		Subtotal	\$14,400
1	Plumbing	\$5,000	
1-A	(installed) <sup>j</sup>	\$5,000	
1	Electrical	\$5,000	
1-A	(installed) <sup>j</sup>	\$5,000	

CALCULATIONS FOR SYSTEMS 2 AND 2-A

System	Item	Cost Calculations	Cost (based on 780,00 gal/yr)
2	Equipment	equipment = \$1,000/yr	\$0.0013/gal
2-A	maintenance <sup>a</sup>	[equipment] \$1,000/yr + [automation] \$5,000/yr = \$6,000/yr	\$0.0077/gal
2	Equipment	$(\$139,700 - 12,600 - 10,000)/10 = \$11,670/\text{yr}$	\$0.0105/gal
2-A	depreciation <sup>b</sup>	$(\$344,300 - 12,600 - 15,000)/10 = \$31,670/\text{yr}$	\$0.0406/gal
2	Membrane	See 1 and 1-A	
2-A	replacement <sup>c</sup>		
2	Electric &		
2-A	chemicals <sup>d</sup>	See 1 and 1-A	
2	Labor <sup>e</sup>	See 1 and 1-A	
2-A			
2	Sample Analysis	See 1 and 1-A	
2-A			
2	Concentrate		
2-A	treatment <sup>f</sup>	See 1 and 1-A	
2	Reverse Osmosis	unit = \$92,300	
2-A	Unit <sup>g</sup>	[unit] \$92,300 + [automation] \$200,000 = \$292,000	
2	Mobilization &		
2-A	Start-up <sup>h</sup>	See 1 and 1-A	
2	Membrane <sup>g</sup>	See 1 and 1-A	
2-A			
2	Support	See 1 and 1-A	
2-A	Equipment <sup>i</sup>		
2	Plumbing/	See 1 and 1-A	
2-A	Electrical (installed)		

CALCULATIONS FOR SYSTEMS 3 AND 3-A

System	Item	Cost Calculations	Cost (based on 780,00 gal/yr)
3	Equipment		
3-A	maintenance <sup>a</sup>	See 2 and 2-A	
3	Equipment	$(\$59,600 - 3,200 - 10,000)/10 = \$4,640/\text{yr}$	\$0.0060/gal
3-A	depreciation <sup>b</sup>	$(\$264,600 - 3,200 - 15,000)/10 = \$24,640/\text{yr}$	\$0.0315/gal
3	Membrane	$(3 \text{ elements}/0.5 \text{ year life}) \times (\$1050/\text{element}) = \$6,300/\text{yr}$	\$0.0081/gal
3-A	replacement <sup>k</sup>	Same as 3	\$0.0081/gal
3	Electric &	See 1 and 1-A	
3-A	chemicals <sup>d</sup>		
3	Labor <sup>e</sup>	$(\$150/8\text{hr day}) \times (7 \text{ day}/\text{wk}) \times (52 \text{ wk}/\text{yr}) = \$54,600/\text{yr}$	\$0.0700/gal
3-A		None	
3	Sample Analysis	(See 1 and 1-A)	
3-A			
3	Concentrate		
3-A	treatment <sup>f</sup>	(See 1 and 1-A)	
3	Reverse Osmosis	unit [used] = \$24,000	
3-A	Unit <sup>g</sup>	[unit ,used] \$24,000 + [automation] \$200,000 = \$224,000	
3	Mobilization &	(See 1 and 1-A)	
3-A	Start-up <sup>h</sup>		
3	Membrane <sup>g</sup>	$(3 \text{ membranes}/\text{RO unit}) \times (\$1050/\text{element}) = \$5,200$	
3-A		(Same as 3)	
3	Support	2 vapor-phase carbon units for tank vents (Tigg, Inc.)	\$ 1,000
3-A	Equipment <sup>i</sup>	2 S.S., 55-gal tanks for chemicals (General Container)	\$ 1,000
		2 1000-gal tanks for feed and permeate (General Container)	\$ 2,400
		1 25' x 8' trailer (Gelco Space)	\$ 5,000
		Pumps (Veasey and Murphey)	\$ 4,000
		Subtotal	\$13,400
3	Plumbing <sup>j</sup>	\$4,000	
3-A	(installed)	\$4,000	
3	Electric <sup>j</sup>	\$5,000	
3-A	(installed)	\$5,000	

CALCULATIONS FOR SYSTEMS 4 AND 4-A

System	Item	Cost Calculations	Cost (based on 780,00 gal/yr)
4	Equipment	[RO] \$5,000 + [MF] \$1,000 = \$6,000/yr	\$0.0077/gal
4-A	maintenance <sup>a, l</sup>	[RO] \$5,000 + [MF] \$1,000 + [RO MF automation] \$10,000 = \$16,000/yr	\$0.0205/gal
4	Equipment	(\$168,400 - 12,600 - 15,000)/10 = \$15,580/yr	\$0.0200/gal
4-A	depreciation <sup>b</sup>	(\$448,700 - 12,600 - 20,000)/10 = \$15,580/yr	\$0.0580/gal
4	Membrane	(12 RO elements/1.5 yr life) x (\$1,050/elements) + \$1,000/yr for MF = \$9,400/yr	\$0.0121/gal
4-A	replacement <sup>c</sup>	Same as 4	
4	Electric &	[(25/MF day) + (50/RO day)] x (4 day/wk) x (52 wk/yr) = \$15,600	\$0.0200/gal
4-A	chemicals <sup>h</sup>	Same as 4	
4	Powdered		
4-A	Activated Carbon <sup>m</sup>	(5g/liter leachate) x (3.785l/gal) x (1 lb/454g) x 780,000 gal/yr x (\$0.94/lb) = \$30,600/yr      4-A same as 4	\$0.0392/gal \$0.0392/gal
4	Labor	See 1 and 1-A	
4-A			
4	Sample	See 1 and 1-A	
4-A	Analysis		
4	Carbon	Not Available	
4-A	Treatment		
4	Concentrate	See 1 and 1-A	
4-A	Treatment		
4	Reverse Osmosis	See 2 and 2-A	
4-A	Unit		
4	Microfiltration <sup>g</sup>	unit = \$23,000	
4-A			
4	Mobilization &	[RO] \$10,000 + [MF] \$5,000 = \$15,000	
4-A	Start-up <sup>h</sup>	[RO] \$10,000 + [MF] \$5,000 + [automation] 5,000 = \$20,000	
4	Membranes	For RO membranes See 1 and 1-A; MF membranes included in unit cost	
4-A			
4	Support	3 vapor-phase carbon units for tank vents (Tigg, Inc.)	\$ 1,500
4-A	Equipment <sup>i</sup>	4 S.S. 55-gal tanks for chemicals (General Container)	\$ 2,000
		4 1000-gal tank for feed and permeate (General Container)	\$ 6,000
		2 25' x 8' trailers (Gelco Space)	\$10,000
		Pumps	<u>\$ 6,000</u>
			SUBTOTAL
			\$25,500
4	Plumbing <sup>j</sup>	\$7,500	
4-A	(installed)	\$7,500	
4	Electric <sup>j</sup>	\$7,500	
4-A	(installed)	\$7,500	

## FOOTNOTES

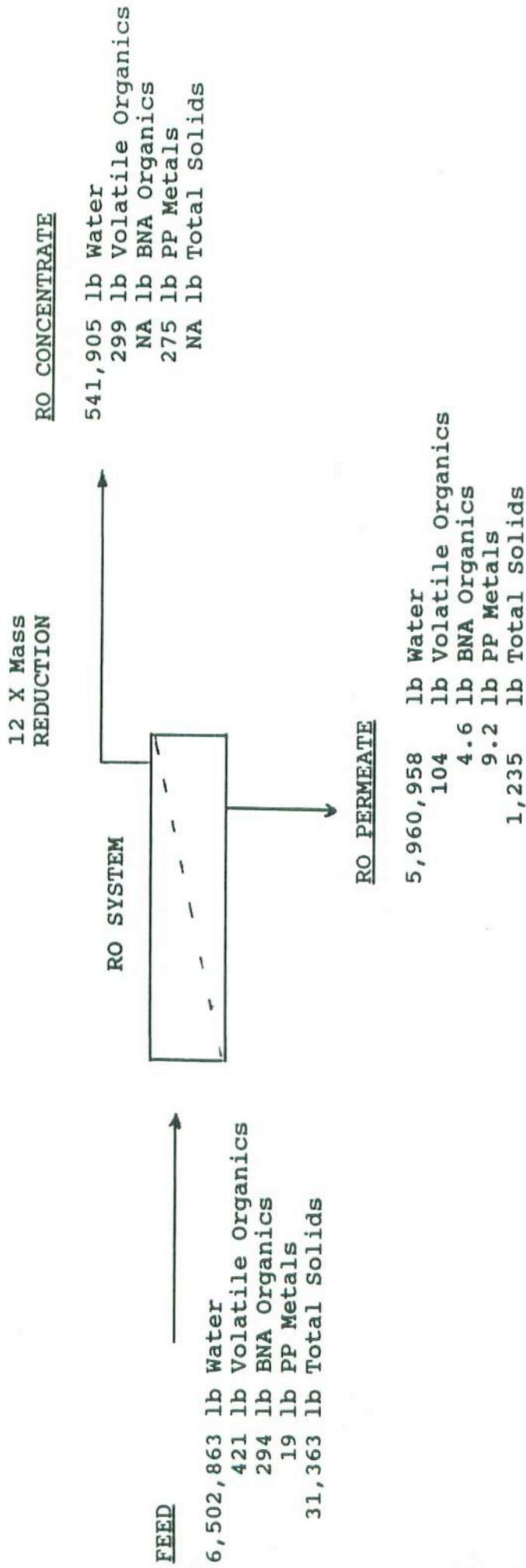
- a equipment maintenance estimated by Sepratek, Ottawa, Ontario; automation maintenance estimated by REAC.
- b 10 year straight-line depreciation (total capital cost - membrane cost - mobilization & start-up)/10.
- c 1.5 yr membrane life based on 6 month expected life operated 24 hours/day; 6 month life estimated by Filmtec, Inc.
- d electric & chemical estimated by Environment Canada.
- e 4 day work week based on treated 65,000 gal/month at 10 GPM = 13.5 8-hr days plus 2.5 days cleaning time.
- f concentrations ratio = 10 and off-site treatment cost of concentrate estimated by REAC.
- g unofficial quote by Sepratek.
- h estimated by Environment Canada and REAC.
- i unofficial quotes.
- j estimated by REAC.
- k 6 month expected life when operated 24 hours/day estimated by Filmtec.
- l microfiltration maintenance estimated by REAC.
- m estimated by Environment Canada.

RO AND PAC/MF/RO

SYSTEM MASS BALANCE

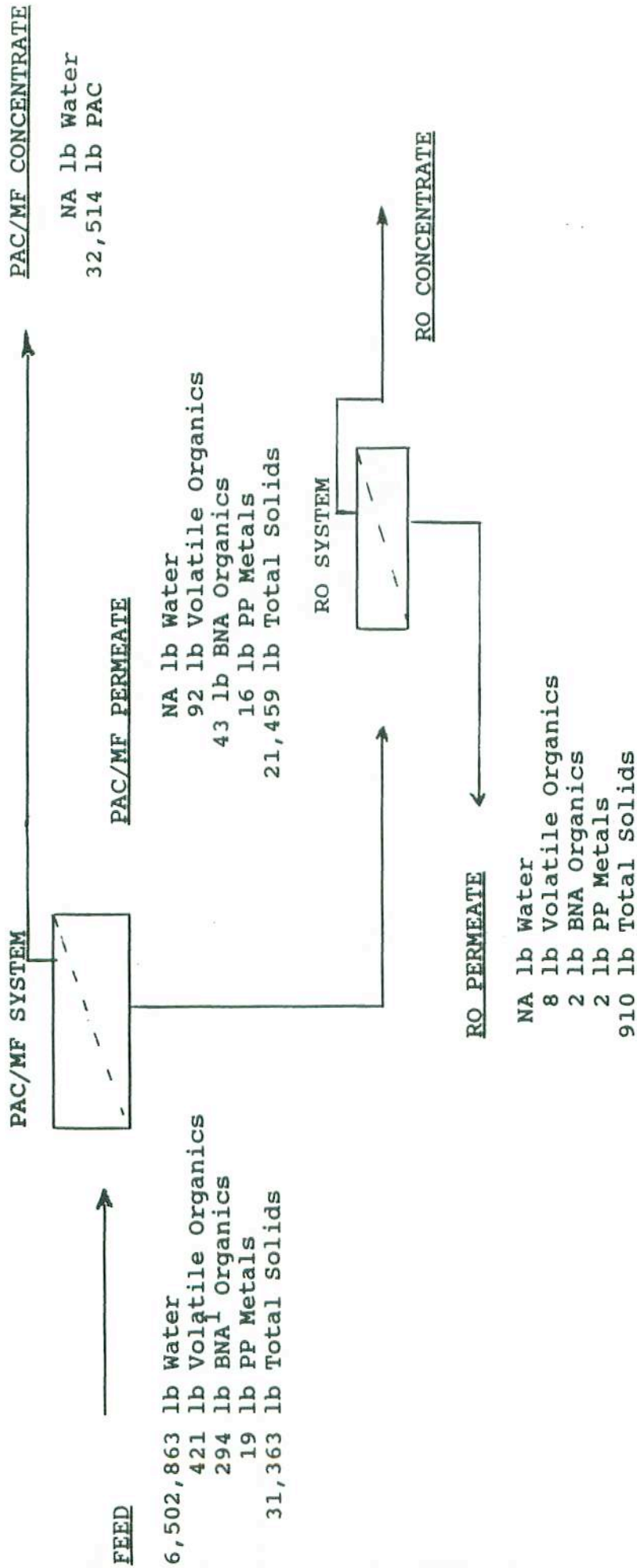
REVERSE OSMOSIS TREATMENT SYSTEM MASS BALANCE

(based on a priority pollutants + 40 scan and assuming 780,000 gallons per year to be treated)



PP = Priority Pollutant  
 BNA = Base Neutral/Acid Extractable  
 NA = Not Available

POWDERED ACTIVATED CARBON/MICROFILTRATION/REVERSE OSMOSIS SYSTEM MASS BALANCE  
 (based on a priority pollutants + 40 scan and assuming 780,000 gallons per year to be treated)



NA = Not Available  
 PP = Priority Pollutants  
 BNA = Base Neutral/Acid Extractable