DEPARTMENT OF THE AIR FORCE
HEADQUARTERS AIR FORCE CIVIL ENGINEER SUPPORT AGENCY

JAN 7 1999

FROM: HQ AFCESA/CES
139 Barnes Drive, Suite 1
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SUBJECT: **Engineering Technical Letter (ETL) 99-1: Treatment and Disposal of Aircraft Washwater Effluent**

1. Purpose. This ETL provides technical criteria and guidance on the treatment and disposal of aircraft washwater effluent. It also contains information to help users determine whether treatment is needed and the type of treatment required. It includes typical wastewater characteristics and specific guidance on selecting, procuring, and implementing treatment and recycling systems.

2. Application: All U.S. Air Force installations that wash or rinse Air Force aircraft, including:

- New construction. Compliance is mandatory for projects in the Project Definition (PD) phase, as well as projects beyond the PD phase, but not yet in active design. Compliance should be considered for projects in active design beyond PD.
- Existing facilities. Compliance is mandatory for all renovation, modification, or alteration activities to the extent possible, and is also mandatory during a major occupancy change, such as a new mission beddown.

2.1. Authority: AFI 32-1067, *Water Systems*.

2.2. Effective Date: Immediately.

2.3. Expiration: Five years from date of issue.

2.4. Recipients: All Major Commands and other Air Force activities.

3. Referenced Publications.

3.1. Executive Order 12088, *Federal Compliance with Pollution Control Standards*

3.2. Public Law:

- P.L. 101-5-8, *Pollution Prevention Act*, 1990
- P.L. 102-386, *Federal Facilities Compliance Act*, 1992
- P.L. 92-500, *Clean Water Act,* 1977 and Amendments

3.3. Code of Federal Regulations (CFR):
- 40 CFR 403, *General Pretreatment Requirements*
- 40 CFR 403.5(b), *Prohibited Discharge Standards*
- 40 CFR 403.5(c), *Local Limits*
- 40 CFR 403.6, *National Categorical Pretreatment Standards*

3.4. Department of Defense (DoD):
- DoD Directive (DoDD) 5100.50, *Protection and Enhancement of Environmental Quality*
- DoD Instruction (DoDI) 4715.4, *Pollution Prevention*
- MIL-HDBK-1005/17, *Nondomestic Wastewater Control and Pretreatment Design Criteria*
- MIL-HDBK-1005/16*, Wastewater Treatment System Design Augmenting Handbook*

3.5. Air Force:
- Air Force Policy Directive (AFPD) 32-70, *Environmental Quality*
- Technical Order (TO) 1-1-691, *Aircraft Weapons Systems Cleaning and Corrosion Control*

3.6. U.S. Army:

3.6.1. U.S. Army Construction Engineering Research Laboratory (USACERL):
- Technical Report TA-94/02, *Recommendations for the Use of Low-Volume, Hot Water, Pressure Washers on U.S. Army Rotary-Wing Aircraft*
- Technical Report N-88/17, *Review of Military and Commercial Aircraft Washing/Cleaning Methods and Facilities*

3.6.2. U.S. Army Center for Public Works (CPW):
- FEAP User Guide 97/120, *User Guide for Implementation of RGF Washrack Recycling Treatment Systems*, September 1997

3.7. Private Industry:
- Science and Engineering Associates, Inc., for U.S. Air Force Reserve Headquarters, Environmental Division, Robins Air Force Base, Georgia, *Guidance for the Management of Washrack Wastewater*, November 1995
- IT Corporation for the Air Force Center for Environmental Excellence, *Dover AFB Environmental Report for the Feasibility Study on the Elimination of the Industrial Waste System*, May 1996

4. Acronyms and Terms.

BOD – biochemical oxygen demand
BTEX – benzene, toluene, ethylbenzene, xylene
COD – chemical oxygen demand
CWA – Clean Water Act
cu m – cubic meter

cu y – cubic yard
DO – dissolved oxygen
EPA – Environmental Protection Agency
FOTW – federally owned treatment works
ft – feet
gpd – gallons per day
gpm – gallons per minute
hp – horsepower
kW – kilowatt
L/s – liters per second
LSI – Langlier Saturation Index
m – meter
mg/L – milligrams per liter
OWS – oil/water separator
NPDES – National Pollutant Discharge Elimination System
POTW – publicly owned treatment works
PPA – Pollution Prevention Act of 1990
SMCL – secondary maximum contaminant level
sq ft – square foot
TDS – total dissolved solids
TPH – total petroleum hydrocarbons
TSS – total suspended solids
USACE – U. S. Army Corps of Engineers
WQA – Water Quality Act

5. Background.

5.1. Purpose of Aircraft Washing. Regular aircraft washing and rinsing prevent and control aircraft corrosion. Removing salt deposits, other corrosive soils, and electro-lytes helps ensure that premature corrosion does not impede the aircraft operation. Regular aircraft cleaning also reduces fire hazards by removing leaking fluid accumu-lations, and enhances the aircraft's aerodynamic efficiency and overall appearance**.**

5.2. Frequency of Aircraft Washing. The Air Force establishes aircraft cleaning schedules. Typically, cleaning of each aircraft is required every 120 days. Washing frequency varies, however, depending on the type of aircraft and its use. More frequent cleaning is necessary if an aircraft is exposed to: (a) salt spray, salt water, or other corrosive materials; (b) excessive exhaust or gun blast soil and exhaust gases within impingement areas; or (c) fluid leakage. Peeling, flaking, or softening of paint may also prompt more frequent cleaning. TO 1-1-691, *Aircraft Weapons Systems Cleaning and Corrosion Control,* outlines specific cleaning requirements.

5.3. Aircraft Washwater Effluent Characterization. Aircraft washwater effluent contaminants typically consist of cleaning agents, oils and grease, jet fuel, hydraulic fluid, paint flakes, and metals. In addition, the alkaline cleaning agents typically used in the washing process may impart a high biochemical oxygen demand (BOD) to the washwater effluent. Table 1 summarizes the median and range of measured contaminants in aircraft washwater effluent, as compiled from a number of Air Force studies (non-detect values are excluded). This table indicates the types and levels of contamination that may be present, though contaminants other than those shown may also be present, and concentrations will depend on site-specific variables, as discussed below. Therefore, sampling and analysis should be conducted to verify actual wastewater characteristics prior to designing any treatment system.

Table 1. Aircraft Washwater Effluent Characteristics at Air Force Bases

Parameter	Units	Median	Minimum	Maximum	No. Analyzed	No. of Detects
Flow	gpd	286	--	7,500	34	26
BOD	mg/L	157	12.0	2,200	40	38
COD	mg/L	560	32.0	20,700	45	45
Cyanide	mg/L	0.02	0.007	2.0	26	10
Oil & Grease	mg/L	32.0	0.1	224,000	61	55
PH	SU	7.5	5.3	8.2	33	26
TPH	mg/L	16.1	0.003	548,000	37	33
TSS	mg/L	47.0	0.3	1,150	52	47
Arsenic	mg/L	0.006	0.004	1.8	45	9
Cadmium	mg/L	0.086	0.005	5.4	75	54
Chromium	mg/L	0.04	0.007	4.6	75	40
Copper	mg/L	0.15	0.008	11	51	39
Lead	mg/L	0.040	0.005	3.5	76	54
Mercury	mg/L	0.0006	0.0001	0.017	50	9
Molybdenum	mg/L	0.027	0.008	0.119	21	4
Nickel	mg/L	0.038	0.005	1.5	50	22
Silver	mg/L	0.040	0.002	0.109	45	11
Zinc	mg/L	0.394	0.04	7.5	69	65
Bis (2-ethylhexyl) phthalate	mg/L	0.092	0.006	0.35	7	6
Phenols	mg/L	0.063	0.010	0.23	16	8
Acetone	mg/L	0.44	0.44	0.44	6	1
Benzene	mg/L	0.50	0.50	0.50	25	1
Ethylbenzene	mg/L	0.25	0.0019	0.50	26	2
Toluene	mg/L	0.00.8	0.0026	3.60	26	4

Source: MIL-HDBK-1005/17, *Nondomestic Wastewater Control and Pretreatment Design Criteria.*

5.4. Factors Affecting Washwater Effluent Characteristics. Washing equipment and procedures, types and amounts of solvent or detergent, the temperature of the washwater, the size and type of aircraft, the type of aircraft paint, and the raw water characteristics all contribute to washwater effluent characteristics.

5.4.1. Washing Equipment and Procedures. The washing equipment and procedures used for aircraft washing affect the amount of water used, which in turn determines the concentration of contaminants in washwater effluent. Washing equipment ranges from a simple hose and bucket to hot water pressure sprayers. Hoses may discharge up to 0.63 liters per second (L/s) (10 gallons/minute [gpm]), while pressure wands normally discharge only 0.12 L/s to 0.25 L/s (2 to 4 gpm).

5.4.1.1. Many bases use cold water, a hose, and a bucket to hand wash aircraft. The bucket is filled with a cleaning compound (detergent) and water solution that is applied to a small area of a wetted aircraft. The surface is scrubbed with a nonabrasive nylon pad or cloth mop, and is then rinsed with fresh cold water. This process is repeated over relatively small areas until the entire aircraft is clean. Hand washing is time consuming and may use more water than other washing techniques.

5.4.1.2. Spray washing is generally the most rapid method of cleaning. The mechanical force of the spray and the chemical and physical actions of the cleaning solution wet and penetrate the soil, and loosen and remove it from the aircraft. Aircraft may also be scrubbed with wash pads or mops if the sprayer does not supply enough agitation. A hot-water spray is generally faster and uses less water; however, bases occasionally use cold-water sprays.

5.4.1.3. Bases sometimes use so-called "foamers" to wash aircraft. This method involves injecting air into a tank containing a soap solution, which rapidly mixes the air and solution as it leaves the tank via a hose. This process produces a very foamy solution that adheres well to the exterior of the aircraft. The solution is allowed to set on the aircraft briefly, or is scrubbed with wash pads or mops, then is rinsed off the aircraft with fresh cold water.

5.4.1.4. Detergent can be added at a pre-set and controlled rate when using foamers or pressure washers for aircraft cleaning. Therefore, these methods are preferred over hand washing, which can not regulate the amount of detergent used. Additional information on washing equipment and procedures in current use may be found in Technical Report N-88/17, *Review of Military and Commercial Aircraft Washing/Cleaning Methods and Facilities*.

5.4.2. Detergent Use. Detergents facilitate oils, grease, and soil removal. However, detergents can damage certain aircraft surfaces and parts if they are not properly diluted and applied. TO 1-1-691 recommends detergents and dilutions for aircraft washing operation and references military specifications. Cleaning solutions more concentrated than those specified in TO 1-1-691 are not recommended, and may actually hamper washing operations because they tend to make surfaces slippery and can impede washing pads from loosening the soils. In addition, concentrated solutions require more rinse water to remove excess cleaner.

5.4.2.1. The type of detergent affects the ability of gravity separators to separate oil from the washwater. Conventional detergents produce stable oil/water emulsions, which render typical gravity separators ineffective. Solvent-type detergents dissolve oil and grease, which also prevent their separation in gravity separators. When permissible, so-called "short-lived" detergents (erroneously referred to as nonemulsifying detergents) should be used to remove oil because they produce an unstable emulsion that dissipates and allows gravity/oil separation.

5.4.2.2. Detergents may impart BOD to the washwater and increase its pH. Therefore, use of excessive amounts of detergents should be avoided.

5.4.3. Water Temperature. Hot-water washing is widely believed to decrease water use and better remove grease and oils. Technical Report TA-94/02, *Recommendations for the Use of Low-Volume, Hot Water, Pressure Washers on U.S. Army Rotary-Wing Aircraft,* reports that cold-water spray "just pushes the grease and oil around on the aircraft," whereas a hot-water spray apparently breaks the bond between the grease/oil and the aircraft, flushing the grease and oil. TA-94/02, using information from washer test studies, indicates that modified hot-water washers reduce or eliminate the need for aircraft surface cleaners. The report found that hot-water washers reduced the cleaning agent used to clean a rotary-wing aircraft by approximately 80 percent, aircraft cleaning times by 20 to 75 percent, and potable water usage 30 to 90 percent. The ranges in savings reflect differences in the washing method used, the cleanliness of the aircraft, and the personnel's familiarity with the equipment and aircraft. Although this study was done on rotary-wing aircraft, the results should apply to fixed-wing aircraft.

5.4.4. Size/Type of Aircraft. Table 2 summarizes the estimated washwater effluent volumes by type of aircraft. Volumes shown for the C-130, F-16, and KC-135 aircraft are based on the responses from a questionnaire survey conducted for this ETL regarding washing equipment and procedures employed at Air Force and Air National Guard installations (see Attachment 1). Volumes shown for the C-141, A-10, and C-5 aircraft were derived from other Air Force wastewater characterization studies. In each case, the methods used to derive the volumes are unknown.

Table 2. Aircraft Washwater Volumes

	Washwater Volume (gallons/wash)	
Aircraft	**Median**	**Range**
C-130	1,300	350 – 5,500
F-16	250	30 – 3,825
KC-135	500	250 – 10,000
C-141	--	1,000 – 2,000
A-10	--	100 – 200
C-5	--	12,000 – 18,000

5.4.5. Raw Water Characteristics. Raw water can significantly impact the metals content of washwater effluent. Corrosive raw water will dissolve metals from building and washwater plumbing systems, including copper from copper pipe, zinc and lead from galvanized pipe, lead from lead solder, and all of these metals (plus chromium, nickel, and cadmium) from brass fittings and faucets. Corrosive water may also leach metals from aircraft, although this impact has not been evaluated. One study at the Dover base identified corrosion of copper piping in the water distribution manifold piping of the washrack area as the probable source of high concentrations of copper in the aircraft washwater effluent (IT Corporation, *Dover Air Force Base Environmental Report for the Feasibility Study on the Elimination of the Industrial Waste System*).

5.4.5.1. These key water quality parameters--pH, alkalinity, hardness, total dissolved solids, and dissolved oxygen--help assess the corrosivity of the water supply. In general, low pH (less than 7.0), low alkalinity and hardness (less than 50 milligrams per liter), and high dissolved oxygen (DO) (values approaching saturation) greatly increase the corrosivity of the water.

5.4.5.2. Measuring the concentration of metals present in the water when it exits the hose or pressure wand will identify plumbing system corrosion and determine whether this corrosion significantly contributes to the metals content of the washwater effluent.

5.4.6. Engine Washing. Jet and turboprop engines and engine components are usually washed separately in a washrack using a steam cleaner. Generally, engine washing takes place in an engine maintenance facility where engines may be removed, disassembled, and reinstalled. A carbon-removing compound may be used in the washing process. Washwater effluent volume is relatively low, usually about 75 to 150 liters (20 to 40 gallons) per engine. However, metals concentrations in washwater effluent may be elevated. Specifically, the C-130 aircraft engines, which contain compressor vanes/blades electroplated with nickel and cadmium, introduce nickel and cadmium into the washwater effluent. Separate containment of this effluent may be beneficial because of its high metals content.

6. Requirements.

6.1. Applicable Regulations/Treatment Requirements. This section provides information on the principal regulations, including local discharge limits, that drive the need for implementing pollution prevention measures and pretreatment systems. The Air Force and all other branches of DoD must comply with Federal, state, and local environmental laws and regulations. The requirements of the Clean Water Act (CWA) and its amendments prohibit the discharge of untreated aircraft washwater effluent to surface waters. These regulations also restrict the discharge of nondomestic wastewater to sanitary sewer systems; therefore, pollution prevention and possibly pretreatment measures are necessary at aircraft washrack facilities. The following paragraphs summarize relevant Federal rules and regulations that apply to washwater effluent.

6.1.1. Pollution Prevention Act. The Pollution Prevention Act (PPA) makes pollution prevention the national policy of the United States. Pollution prevention is defined in the PPA as "…*any practice which reduces the amount of a hazardous substance, pollutant, or contaminant entering any waste stream or otherwise released into the environment (including fugitive emissions) prior to recycling, treatment, or disposal; and any practice which reduces the hazards to public health and the environment associated with the release of such substances, pollutants, or contaminants.*"

6.1.1.1. The goals of the PPA state that "*pollution should be prevented or reduced whenever feasible; pollution that cannot be prevented should be recycled in an environmentally safe manner, whenever feasible; pollution that cannot be prevented or recycled should be treated in an environmentally safe manner whenever feasible; and disposal or release into the environment should be employed only as a last resort*."

6.1.1.2. The primary goal of the PPA is reducing the amount of pollutant that enters a waste stream or that is otherwise released into the environment prior to out-of-process recycling, treatment, or disposal.

6.1.2. Federal Facilities Compliance Act. Installations discharging to their own federally-owned treatment works (FOTWs) historically have not been subject to Federal pretreatment regulations. However, the proposed rules implementing the Federal Facilities Compliance Act subject FOTWs to hazardous waste disposal and pretreatment requirements similar to publicly owned treatment works (POTW) requirements whenever any individual activity at the installation generates more than 100 kilograms (220 pounds) of hazardous waste per month, or generates acutely hazardous waste of any quantity. In such cases, the FOTW's host installation will administer the pretreatment requirements.

6.1.3. General Pretreatment Regulations. 40 CFR 403, *General Pretreatment Regulations*, has been the basis for the development and implementation of local pretreatment programs throughout the United States since 1978. The regulations set forth *Prohibited Discharge Standards* [40 CFR 403.5(b)] that apply to all non-domestic discharges to a POTW, and they establish an administrative mechanism to apply and enforce these discharge prohibitions, as well as *Local Limits* [40 CFR 403.4(c)] and *National Categorical Pretreatment Standards* (40 CFR 403.6). Aircraft washwater effluent discharged to POTWs is subject to meeting the prohibited discharge standards and local limits, but is not subject to national categorical pretreatment standards. The state or U.S. Environmental Protection Agency (EPA) may enforce the regulations directly if the POTW does not have an approved pretreatment program. Under proposed guidance, bases discharging to an FOTW will also be subject to some pretreatment requirements.

6.1.3.1. The prohibited discharge standards restrict discharge of the following pollutants to a sanitary sewer system:

- Pollutants that could create a fire or explosion hazard (e.g., fuels).
- Corrosives that could cause structural damage.
- Solid or viscous pollutants that could obstruct flow.
- Heat in amounts that could inhibit biological activity.
- Pollutants at a flow rate and/or concentration that could interfere with treatment processes.
- Pollutants that could produce toxic gases, vapors, or fumes within the sewer system in quantities endangering workers.
- Trucked or hauled industrial wastewater pollutants, except at approved discharge points.

6.1.3.2. POTWs subject to 40 CFR 403 are required to develop and enforce technically-based local limits. Local limits are specific concentration limits for pollutants that may be discharged to a sanitary sewer system. The limits are written to protect plant processes, effluent and biosolids quality, and worker health and safety. Most POTW local limits regulate heavy metals, cyanide, and oil and grease. Some POTWs have also established local limits for toxic organics, such as benzene, toluene, ethylbenzene, and xylene (BTEX compounds).

6.1.3.3. Local limits are typically enforceable where the building lateral enters the sanitary sewer. For military installations, the POTW may choose to enforce limits at locations that combine several nondomestic sources or at the final connection point(s) of the base with the POTW system. FOTWs may also develop local limits, which would be applicable to base nondomestic discharges.

6.1.3.4. Local limits vary from POTW to POTW due to different treatment processes, pollutant removal efficiencies, receiving water discharge standards, residual solids disposal standards, domestic wastewater pollutant background concentrations, and industrial wastewater contributions. The values presented in Table 3 summarize local limits from several locations, including 18 installations that discharge to POTWs, and 11 additional POTWs located around the U.S. MIL-HDBK-1005/17 provides guidance on the development of technically-based local limits to control pollutant discharges from nondomestic Air Force sources. The guidance presented within that handbook is also useful in assessing whether local limits developed by the POTW are reasonable and defensible.

Table 3. Summary of Local Limits from Several U. S. Cities

	As	Cd	Cr	Cu	Pb	Hg	Mo
Median	0.38	0.23	2.0	2.07	0.63	0.015	0.23
Maximum	2.0	8.0	25.0	25.0	10.0	5.0	0.42
Minimum	0.026	0.02	0.05	0.02	0.017	0	0.06

	Ni	Ag	Zn	O&G	BETX	CN
Median	2.38	0.50	2.6	100	17.5	0.77
Maximum	11.0	7.8	25.0	500	70.0	9.8
Minimum	0.025	0.01	0.05	50.0	1.5	0.01

Source: MIL-HDBK-1005/17.
Note: All units in mg/L.

6.1.3.5. Most POTWs have local sewer-use ordinances, which contain prohibited discharge standards and local limits, as described above, as well as other conditions governing use of the POTW's sewer system. Local sewer-use ordinances may require certain nondomestic wastewater sources, including Air Force installations, to obtain a wastewater discharge permit and to perform self-monitoring. Air Force installations must comply with all provisions of local sewer-use ordinances and should cooperate with POTWs in their enforcement of local ordinances.

6.2. Washwater Effluent Management Options. In the past, recycling systems at aircraft washracks have focused on water conservation and pollution prevention. While recycling systems reduce water consumption, they merely concentrate pollutants into a smaller volume and do not necessarily reduce the quantity of pollutants released to the environment or requiring disposal. If recycled water is not properly monitored, it can actually promote corrosion on aircraft surfaces through excessive concentrations of chlorides or other corrosion-inducing constituents. Therefore, the PPA should not be used to justify implementing a washwater effluent recycling system; rather, a washwater effluent management system should be selected after carefully considering these four washwater effluent management options:

- Discharging untreated washwater effluent to a wastewater system.
- Discharging pretreated washwater effluent to a wastewater system.
- Treating and recycling the washwater effluent.
- Collecting the washwater effluent and hauling offsite for disposal.

Because direct discharge of aircraft washwater effluent to a surface water under a National Pollutant Discharge Elimination System (NPDES) permit is not practical, it is not considered in this ETL. Figure 1 presents a decision diagram for selecting the most appropriate washwater effluent management option. In general, the least expensive option that meets environmental and regulatory criteria should be used. Usually, discharging effluent to a sanitary sewer is the least expensive option that meets Federal and DoD requirements.

6.2.1. Discharge to Sanitary Sewer (No Treatment). Discharging washwater effluent to a sanitary sewer without treatment is the most widely practiced washwater effluent management option. For standard washing procedures, it is also the preferred option. Other options should be considered only if the washwater effluent can be characterized by answering “Yes” to any of the following questions.

> **Question 1:** ***Do high water supply and wastewater disposal costs warrant consideration of other alternatives?***
>
> In certain rare instances, water supply and/or sanitary sewer disposal costs may be high enough to warrant consideration of other less expensive options.
>
> **Question 2:** ***Does a water shortage mandate conservation?***
>
> Drought conditions or a general water shortage may mandate water conservation. Such circumstances are rare but, when present, supersede the otherwise preferred option of sewer discharge. It should be noted, however, that recycling systems offer limited potential for conserving water because water lost through evaporation and blowdown must be replaced (see paragraph 6.4).
>
> **Question 3:** ***Does the washwater effluent violate discharge limits?***
>
> Typically, aircraft washwater effluent complies with local limits, rendering pretreatment unnecessary. As noted previously, local limits may not apply at the

point of washwater effluent discharge to the military sanitary sewer, but rather may apply at a point further downstream after the effluent has been diluted. The local POTW should be consulted to determine applicable discharge requirements. Even in cases where effluent can exceed local limits for one or two parameters, POTWs often have the ability to issue discharge permits with specific variances.

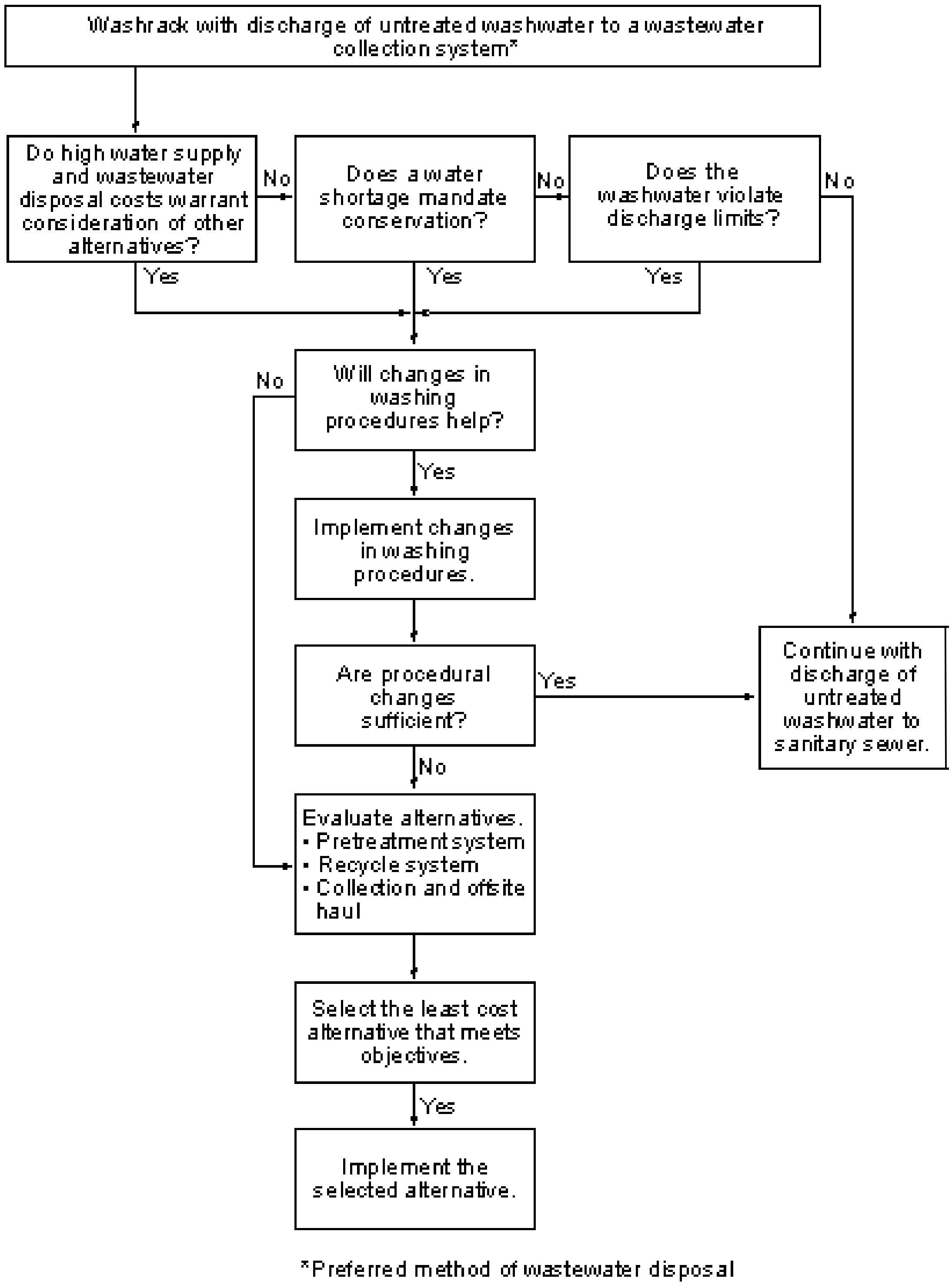

Figure 1. Decision Diagram for Selecting the Appropriate Treatment/Disposal Option for Aircraft Washwater

6.2.2. Pretreatment and Discharge to Sanitary Sewer.

6.2.2.1. As indicated previously, oil and grease and heavy metals are the most common contaminants limited by POTW requirements. If effluent contaminants exceed local limits, oil and grease and heavy metals removal may be required prior to discharge to a sanitary sewer. Treatment systems for washwater effluent are discussed in paragraph 6.3.

6.2.2.2. As shown in Figure 1, pollution prevention methods should be evaluated before pretreatment is considered. If the effluent contains elevated levels of metals, the water supply to the washrack should be investigated to ensure that plumbing system corrosion did not cause or contribute to the elevated concentrations.

6.2.3. Recycling. The use of treatment/recycling systems should be considered only if they are potentially cost effective, if water conservation is mandated, or if extensive treatment is required for sewer discharge. If recycling washwater effluent is the most beneficial option, it is essential that the treatment system is designed to treat the water adequately to prevent corrosion of the aircraft and remove detergent and film from the aircraft. Consultation with the National Association of Corrosion Engineers, Corrosion and Protection Center, International Corrosion Council, and several other corrosion groups and databases did not yield published information regarding acceptable water quality guidelines for aircraft washing. In the absence of such information, the water quality guidelines summarized in Table 4 are recommended based on general corrosion principles. These guidelines are further discussed in the following subsections, while information on treatment/recycling systems is given in paragraph 6.3.

Table 4. Recycle Water Quality Guidelines

Parameter	Recommended Value
Chlorides	< 400 mg/L
pH	6.5 – 8.5
TDS	< 500 mg/L
TSS	<5 mg/L
LSI	Slightly above zero
BOD	< 5 mg/L
Microorganisms	Provide adequate disinfection
Hardness	75-150 mg/L as $CaCO_3$
TPH	< 10 mg/L

6.2.3.1. Chlorides are the primary corrosion-inducing materials removed from aircraft during washing or rinsing, particularly in coastal areas. TO.1-1-691 specifies that aircraft should be washed and rinsed with clean water containing less than 400 milligrams per liter chloride levels, which is somewhat higher than the EPA drinking water standard of 250 milligrams per liter.

6.2.3.2. Chlorides exist in a soluble form in water. They can be removed by reverse osmosis, but conventional package recycling systems don't include this process. Therefore, evaporation and chloride input from makeup water increase the chloride concentration through recycling until an equilibrium concentration is reached. In many locations, particularly coastal areas, the equilibrium concentration of chlorides is likely to be higher than 400 milligrams per liter. The equilibrium concentration depends on the amount of chlorides washed from the aircraft, the volume of fresh water makeup within the recycling system, the chloride concentration of the makeup water, and evaporation rates.

6.2.3.3. If a recycling system is necessary for aircraft washing, the chloride level of the recycled water must be monitored. Makeup water additions should be adjusted to maintain chloride concentrations below 400 milligrams per liter. Daily makeup water requirements may range from 25 to 50 percent or more of the total water volume required for washing. The high makeup water requirement significantly reduces the water conservation efficiency of recycling systems.

6.2.3.4. Washwater effluent pH indicates effluent alkalinity or acidity. Washwater effluent is typically slightly alkaline, with a pH ranging between 7 and 9. If washwater effluent is recycled, it should be treated so that the pH is within the range 6.5 to 8.5.

6.2.3.5. Total dissolved solids (TDS) include chlorides plus other soluble constituents. As with chlorides, TDS concentrations can build up in recycling systems until equilibrium is reached. No TDS standard has been established for aircraft washing, but it is recommended that the TDS concentration of recycled washwater effluent be maintained below the EPA secondary maximum contaminant level (SMCL) recommendation of 500 milligrams per liter.

6.2.3.6. Total suspended solids (TSS) removal should be included within recycling systems to maximize disinfection effectiveness and to minimize abrasion when the recycled water is sprayed under pressure. A maximum level of 5 milligrams per liter in the treated washwater effluent is recommended.

6.2.3.7. The Langlier Saturation Index (LSI) is a corrosion index based on the degree of calcium carbonate saturation. If the LSI is greater than zero, the water is supersaturated and tends to precipitate a scale layer of $CaCO_3$. If the LSI equals zero, water is in equilibrium with $CaCO_3$, and if it is below zero, the water is undersaturated and will tend to dissolve solid $CaCO_3$. As with potable water, an LSI value slightly above zero is believed to be an optimal level for aircraft washwater.

6.2.3.8. The organic content of washwater effluent is usually measured by BOD or COD. To control odor, recycling systems must include a means of removing dissolved organic matter, usually activated carbon adsorption. A BOD concentration of less than 5 milligrams per liter in the treated washwater effluent is recommended.

6.2.3.9. Washwater effluent recycling systems should include a disinfection process, such as ozonation, to control the growth of microorganisms.

6.2.3.10. Water hardness (calcium and magnesium content) may affect aircraft cleaning operations. Water that is too hard may leave a residue on the aircraft. A hardness of between 75 and 150 milligrams per liter as $CaCO_3$ is typically the accepted range for potable water and is also recommended for aircraft washwater.

6.2.3.11. The presence of TPH in recycled washwater may impact the cleanliness of the aircraft. The recommended upper limit of 10 milligrams per liter for TPH is based on the capability of conventional washwater recycling systems and is consistent with drinking water standards, which allow up to 10 milligrams per liter of total xylenes (a TPH compound).

6.2.4. Offsite Hauling. In some cases, collecting washwater effluent and hauling it offsite for disposal may be cost-competitive with other management options, particularly the pretreatment or recycling options. Collection and offsite hauling may also be warranted where skilled personnel are not available to operate pretreatment or recycling systems. For engine washwater effluent, separate collection and treatment or offsite hauling is the preferred handling methods because metals concentrations are typically high while washwater effluent volumes are low.

6.3. Washwater Effluent Treatment Systems. Processes used to treat aircraft washwater effluent for discharge to the sewer or for recycling may include sedimentation, filtration, oil removal, coagulation, flocculation, neutralization, oxidation, adsorption, ion exchange, reverse osmosis, and precipitation. Packaged treatment systems may be purchased from various manufacturers that combine the unit processes most frequently needed. Companies manufacturing pre-fabricated treatment systems are listed in *Guidance for the Management of Washrack Wastewater* (Science and Engineering Associates, Inc.) and MIL-HDBK-1005/17. An engineered design may be preferable, in some cases.

6.3.1. Oil Removal. Washwater effluent may contain fuel and lubricants, measured as oil and grease, in concentrations that exceed local limits. Oil may be classified as free, emulsified, or dissolved. Free oil contains oil droplets large enough to rise to the surface and form an oily layer on top of the water surface. Emulsified oil consists of smaller droplets dispersed within the water, which are not buoyant enough to rise to the water surface without chemical treatment. Dissolved oil is soluble in water.

6.3.1.1. A decision diagram to assist in determining whether oil removal is necessary is shown in Figure 2. Oil removal should be undertaken only if the level of oil discharged exceeds allowable discharge standards and these standards cannot be met with pollution prevention techniques. If oil removal is necessary, then the selection of separation equipment should take into account the levels of free and emulsified oil.

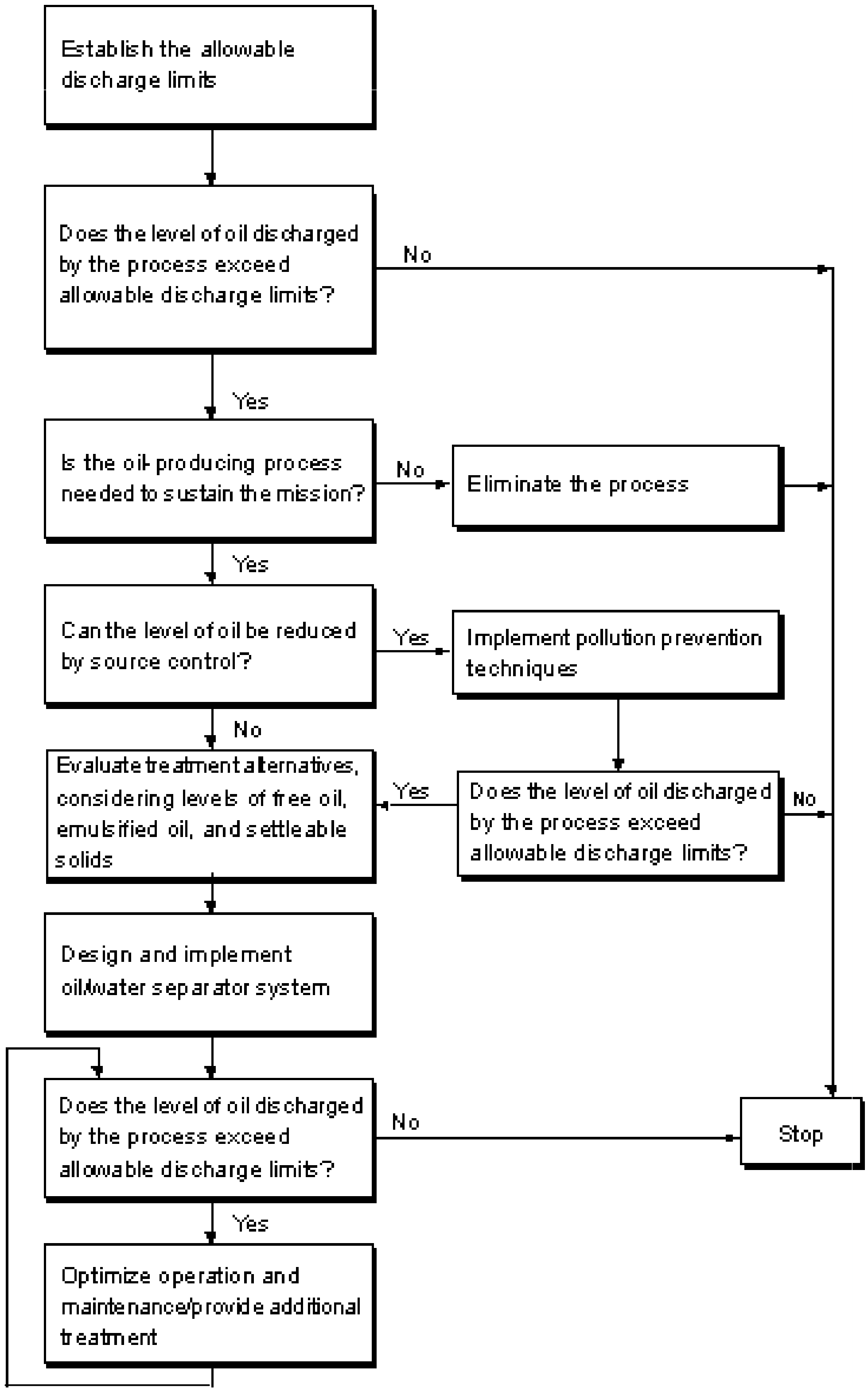

Figure 2. Decision Tree for Oil/Water Separators

6.3.1.2. Under proper quiescent conditions, conventional gravity separation can remove free oil. Emulsified oil cannot be removed by gravity separation unless it can first be converted to free oil by breaking the emulsion. A short-lived, unstable emulsion-forming detergent can break up the emulsion sufficiently for gravity separation to be effective. Otherwise, air flotation can remove emulsified oil, although the emulsion may first have to be broken for this process to be effective. Removal of soluble (dissolved) oil is rarely required at military installations but may be accomplished by biological treatment or adsorption onto a solid phase sorbent, such as activated carbon (MIL-HDBK-1005/16, *Wastewater Treatment System Design Augmenting Handbook*).

6.3.1.3. Solvents, phenols, dissolved metals, and other toxic and hazardous pollutants are not effectively removed by oil/water separation technology and may require additional source control or pretreatment. Some of these toxic materials may, however, be removed by the oil/water separator, which can render the sludge hazardous.

6.3.1.4. Additional information on the selection and design of oil/water separators is presented in MIL-HDBK-1005/17. Information relating to U.S. Army oil/water separator research efforts may be accessed at the following World Wide Web address: http:/www.plaii.com/oilwater. Air Force information on oil/water separation may be found at http://www.afcee.brooks.af.mil/pro_actform.htm.

6.3.2. Metals Removal. Metals may be present in aircraft washwater effluent in both particulate and dissolved forms. The metals may originate from the metallic surfaces of the aircraft and, as noted previously, from the washwater supply itself, particularly through plumbing system corrosion. In general, metals resulting from washing the outside surfaces of aircraft have not proven to be a significant problem. However, high levels of cadmium and nickel have been detected in aircraft engine washwater effluent, particularly for the C-130. The metals most likely to be of concern in aircraft washwater effluent are cadmium, chromium, copper, lead, nickel, and zinc.

6.3.2.1. Particulate metals can be removed from wastewater by conventional physical processes, such as sedimentation and filtration. Dissolved metals are most commonly removed by chemical precipitation followed by flocculation, sedimentation, and filtration. Dissolved metals may also be removed by ion exchange. Proper selection and design of these processes is discussed in MIL-HDBK-1005/17.

6.3.2.2. Metals removal treatment processes typically require a high level of maintenance and generate a metal-laden sludge that may be classified as a hazardous waste. Hazardous waste requires separate handling and compliance with appropriate RCRA requirements.

6.3.2.3. Metals removal processes should be considered only when a discharge is out of compliance and pollution prevention methods are insufficient. Even then, alternative wastewater management systems should be evaluated.

6.3.3. Treatment Systems for Washwater Effluent Recycling. Treatment systems for washwater effluent recycling may be custom-engineered or purchased as pre-engineered, factory-fabricated package treatment systems. Virtually all systems incorporate oil removal and filtration. Some incorporate activated carbon treatment to remove soluble organics, membrane treatment to removal inorganics and/or organics, and ozonation to control microorganisms. In addition, these systems should include an influent flow equalization basin and a treated water storage vessel to minimize the required capacity of the treatment system while delivering the required flow of recycled water to the user. In evaluating systems, select one that provides an appropriate level and capacity of treatment. Systems that provide unnecessary treatment processes increase costs and operation and maintenance (O&M) requirements.

6.3.4. Byproduct Disposal. Pretreatment and recycling systems generate concentrated waste byproducts in the form of sludge and oil. These byproducts must be periodically removed and disposed offsite, sometimes as a hazardous waste. The costs of byproduct disposal must be included in the overall cost analysis of alternatives.

6.4. Cost Estimates for Recycling/Treatment Systems.

6.4.1. Construction Costs. Order-of-magnitude construction cost estimates based on 1998 dollars were developed for package recycling treatment systems for four different treatment capacities. An order-of-magnitude estimate relies on manufacturer-supplied prices for equipment and generalized installation cost factors and allowances. The accuracy of such estimates typically ranges from –30 to +50 percent of the actual final construction cost of the system. A summary of the estimates is given in Table 5.

Table 5. Installed Equipment Costs for Washwater Recycling Systems

Treatment Capacity		Estimated Cost[a]
L/s	gpm	($)
0.630	10	25,500
1.577	25	39,000
3.154	50	61,500
6.308	100	102,500

[a] 1998 Dollars

6.4.1.1. Equipment estimates were obtained from three manufacturers. Allowances were then added for equipment installation (30 percent), contractor mobilization and contingency (15 percent), instrumentation and control (6 percent), engineering (20 percent), piping connections ($2,500), and power supply ($2,500). The systems from different suppliers varied somewhat but generally included gravity oil/water separation with coalescing plates, multi-media filtration, activated carbon adsorption, ozone disinfection, and pH adjustment. If the selected system involves treatment and discharge to a sanitary sewer system, some of these processes would not be required, and costs would be lower. However, inclusion of additional processes, such as reverse osmosis for removal of dissolved salts, would increase the costs.

6.4.1.2. Specific construction tasks and equipment/piping requirements vary from site to site. For example, some installations may require additional items such as concrete slabs, a building enclosure, an influent wet well, and a treated water storage tank. These items are not included in the preceding installed equipment costs but may be estimated from unit costs presented in Table 6.

Table 6. Estimated Unit Costs for Recycle/Treatment System Appurtenances

Item	Unit Cost[a]
Sump and 1.12 kW (1.5 hp) duplex pumps	$8,500
Sawcut concrete	$14.11/m ($4.30/ft)
Remove concrete (6" thick, reinforced)	$258/sq m ($24/sq ft)
Metal roof cover plus supports (installed)	$323/sq m ($30/sq ft)
Metal building (installed)	$582/sq m ($75/sq ft)
Concrete slabs (new)	$582/cu m ($445/cu yd)
Concrete patching	$785/cu m ($600/ cu yd)
1,000 gallon fiberglass reinforced plastic storage tank	$6,700
2,000 gallon fiberglass reinforced plastic storage tank	$8,700
5,000 gallon fiberglass reinforced plastic storage tank	$11,000
10,000 gallon fiberglass reinforced plastic storage tank	$14,200

[a] 1998 Dollars

6.4.2. O&M Costs.

6.4.2.1. O&M costs for recycling treatment systems may include the following:

- operations labor
- electricity
- makeup water
- maintenance, repairs materials, and labor
- byproduct handling and disposal
- laboratory
- chemicals and other consumables

6.4.2.2. Order of magnitude O&M cost estimates prepared for the four sizes of recycling treatment systems are shown in Table 7. The estimates were based on the following assumptions:

- Operational labor requires 2 hours per week for the 0.630 to 1.577 liter-per-second (10 to 25 gallon-per-minute) systems, 3 hours per week for the 3.154 liter-per-second (50 gallon-per-minute) system, and 4 hours per week for the 6.308 liter-per-second (100 gallon-per-minute) system.
- Labor rates, including benefits, are $20 per hour.
- Annual consumable costs (e.g., carbon, filter replacements) equal 5 percent of the installed equipment cost.
- Electrical/power requirements cost of $0.08 per kilowatt-hour.
- Additional miscellaneous maintenance costs: $200 per month.

- Makeup water is 40 percent of the water treated and costs $2.00 per 3,785 liters (1,000 gallons).
- Sludge production is 3 percent of the water treated and costs $200 per 3,785 liters (1,000 gallons) for disposal.

Table 7. Estimated O&M Costs for Washwater Recycling Systems

Treatment Capacity		Estimated Cost[a] ($)
L/s	gpm	
0.630	10	12,700
1.577	25	23,100
3.154	50	41,700
6.308	100	76,800

[a] 1998 Dollars

6.4.3. Total Annual Costs. The total annual costs of recycling systems were determined by adding annual O&M costs to annualized capital costs. These estimates are summarized in Table 8. Annual capital costs were calculated by amortizing total capital costs over a 10-year period at 6 percent interest. Unit costs in dollars per 3,785.30 liters (1,000 gallons) of treated washwater effluent were then computed, assuming that the recycling system operated at full capacity for an average of 6 hours per day, 260 days per year. (Unit costs would be higher for less frequent operation).

Table 8. Total Annual Costs and Unit Costs for Washwater Recycling Systems

Treatment Capacity (gpm)	Total Annual Cost[a] ($/year)	Unit Cost of Treatment[a] ($/3,785.30 liters [1,000 gallons])
10	16,100	22.40
25	28,400	15.78
50	50,100	13.91
100	90,800	12.61

[a] 1998 Dollars; Estimates do not include additional site-specific costs.

These costs should be considered as rough estimates. In addition to variations in the assumed operating conditions, unit costs will depend on other factors, such as the washwater effluent characteristics and the degree of treatment provided.

6.4.4. Comparison to Other Washwater Effluent Management Options.

6.4.4.1. Discharging to a POTW with or without pretreatment is less expensive than recycling effluent. Nationally, municipal wastewater user charges average approximately $2.25 per 3,785.3 liters (1,000 gallons). Potable water rates average about $2.00 per 3,785.3 liters (1,000 gallons). At these charge rates, recycling systems are not cost effective.

6.4.4.2. Costs for disposal of aircraft washwater effluent via truck haul to a remote disposal site vary depending on haul distance and the washwater effluent characteristics. In 1996, one Air Force base spent $112,000 to haul approximately 1,514,120 liters (400,000 gallons) of washwater effluent, which is equivalent to a unit cost of $280 per 3,785.3 liters (1,000 gallons). Thus, offsite hauling is likely to be more expensive than recycling washwater effluent.

6.5. Selecting and Purchasing Treatment/Recycling Equipment.

6.5.1. Process Selection. Equipment must be selected to treat the washwater's specific effluent characteristics, derived from onsite sampling. Highly variable flow rates and variations in suspended solids, oil, metal, or salt concentrations may significantly affect system performance and must be accounted for in process selection and sizing. Improper system design may result in excessive capital and O&M costs and/or inadequate treatment performance. Consulting engineers should be retained on larger projects that need an independent evaluation of alternative processes or equipment requiring a customized design.

6.5.2. Equipment Selection. Purchasers of treatment systems should be familiar with the capabilities and constraints of the equipment to ensure that the selected equipment can produce the desired results for a particular application. Manufacturer's literature and sales representatives' claims may be misleading. The following is a general approach to selecting equipment and working with equipment vendors:

- Define the local wastewater problem, including scope of work, budget, and schedule, before calling a vendor.
- Establish what the vendor will be expected to provide.
- Identify more than one vendor who can provide the needed equipment and services.
- Solicit written proposals from competing vendors for equipment and services, including a cost estimate.
- Request that vendors test their equipment at the local site, or visit other sites where the vendor's equipment is installed (preferably military installations with similar applications).
- Select the vendor based on experience, qualifications, and reputation, as well as cost.

6.5.3. Warranty and Contract Arrangements. Purchasing equipment through a General Services Agreement (GSA) contract ensures the lowest price for a treatment unit and that this price will include startup training. However, GSA procurement does not provide flexibility for modifying the equipment or services, and it excludes non-GSA vendors who could provide quality equipment and services at competitive prices. In addition, the installation of major pieces of equipment usually requires a general contractor. Often, allowing a general contractor to install government-furnished equipment results in more complex contract management issues than having the general contractor furnish and install the equipment under a single contract.

6.5.3.1. Adequately training personnel to operate and maintain treatment equipment is necessary to ensure that equipment operates to its design potential. To ensure sufficient training, the purchase agreement should include a statement requiring the vendor to provide at least 2 hours of training. The training should include the following:

- a demonstration of procedures involved in operating and maintaining the system.
- supervised operation and maintenance of the system by Air Force personnel.
- an explanation of simple repair procedures Air Force users can perform without affecting the warranty.
- a page-by-page explanation of the content of the operation/ maintenance manual.

6.5.3.2. The vendor should also provide a specified number of copies of the manual(s) and O&M videotapes for the system.

6.5.4. Performance Testing. Following installation, the installing contractor should be required to:

- Inspect and clean equipment, devices, and connected piping.
- Lubricate equipment in accordance with the manufacturer's instructions.
- Check any power supply to electric-powered equipment for correct voltage.
- Obtain manufacturer's certification of proper installation.
- Submit certification that the installation is in compliance with the manufacturer's recommendations.

6.5.4.1. The contractor should notify the military installation of equipment and system readiness for testing, completion of O&M manuals, completion of manufacturer's certification of proper installation, and availability of manufacturer's representative to assist with testing equipment. After such notification, the manufacturer should complete equipment performance testing.

6.5.4.2. Performance testing should require the manufacturer to start and operate the treatment system to test each piece of equipment. If the equipment performs to the standards specified, it can be accepted. If the treatment equipment does not conform to the conditions of the performance test, the system should not be accepted until the manufacturer has made such adjustments, changes, and additions as necessary to correct the system.

6.5.5. Service/Lease Contracts. Maintenance of a treatment system is critical to the system's performance. If personnel are not assigned responsibility and/or adequately trained to perform maintenance duties, a service contract should be negotiated with a nearby provider. The service agreement should detail the services the provider will furnish for an agreed-upon monthly fee.

7. Point of Contact: Mr. Myron Anderson, HQ AFCESA/CESC, DSN (523-6345), commercial (850) 283-6470, FAX (850) 283-6219, or email: andersom@afcesa.af.mil.

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Director of Technical Support

Atch (2)
1. Washwater Estimates
2. Distribution List

Air Force Base Aircraft Washwater Estimates

Base	Aircraft	Wash Duration (hours*)	Volume Estimate (liters)	(gallons)
Osan	A-10, F-16	3 - 6	908	240
Eielson	A-10, F-16, F-15	8	6,814	1,800
Dyess	B-1B, C-130	8 - 12	15,141	4,000
Peterson	C-130	1.5 days		
Kirtland	C-130	7	15,141	4,000
McChord	C-130	4	1,136	300
Yokota	C-130, C-9	8	1,514	400
Elmendorf	C-130, F-15	2	2,271	600
Kadena	C-130, RC-135, KC-135	6	3,785	1,000
Hickam	C-130H	4	1,136	300
McChord	C-141B	4	4,542	1,200
Altus	C-141B	6		
McChord	C-17	4		TBD
Altus	C-17	6		
Altus	C-5	12		
Tyndall	F-15	6	1,892	500
Hickam	F-15 A/B	4	757	200
Kadena	F-15C/D	3	2,650	700
Seymour Johnson	F-15E	4 –5		
Shaw	F-16	4		
Luke	F-16	4	757	200
Nellis	F-16, F-15, F-18, A-6, A-10	2	14,478	3,825
Keflavik	HH-60, F-15	3	1,324	350
Hickam	K-135R	4	1,514	400
Fairchild	KC-135	4 –5		
Altus	KC-135	4		
Eielson	KC-135R	10		
Eielson	KC-135R	8	1,892	500
Tinker	KC-135R	2 –2.5 days		
Randolph	T-1	4	30,282	8,000
Columbus	T-1A, T-37, AT/T-38	1.5		
Randolph	T-37	2	22,711	6,000
Sheppard	T-37, T-38, AT-38	3		
Laughlin	T-37, T-38, T-1	2 –3	7,570	2,000
Vance	T-37, T-38, T-1	2	379	100
Randolph	T-38	2	22,711	6,000
Holloman	T-38, F-4	6 –8	18,926-30,282	5-8,000
Randolph	T-43	8	273 kL	72,000
Anderson				

* Unless otherwise indicated.

Air National Guard Aircraft Washwater Estimates

Guard Unit	Aircraft	Wash Duration (hours*)	Volume Estimates (liters)	(gallons)
Connecticut – 103	A-10, OA-10	8	3,785	1,000
Maryland – 175	A-10A	8	662	175
Maryland – 175 WG	C-130	30 man hours		
Nevada – 152 AW	C-130	6	1,514	400
New York – 109 AW	C-130	40		
Wyoming – 153 AW/MXS	C-130, K-3	15	5,677-7,571	1,500-2,000
Delaware	C-130-B	6		1,600
California – 146 AW	C-130E	4 – 6		
Minnesota – 133	C-130H	4	18,926	5,000
Tennessee – 118 AW	C130-H	24		
Kentucky – 123 MXS	C-130-H	24		350
Ohio – 910 AW/MXS/LGMF	C-130H (H-2)	24	18,926-22,711	5 – 6,000
Missouri – 139 AW	C-130-H2	6 – 8	15,141-22,211	4 – 6,000
Mississippi – 172 AW	C-141B	12		
March ARB	C-141B, KC-135	18	10,031	2650
Pennsylvania – 193 SOW	EC-130E	48	327 kL	86,400
Indiana – 122 MXS	F-16	4	189	50
Iowa – 132 FW	F-16	4		
Montana – 120 FW	F-16	2	568	150
New York	F-16	2	379	100
Ohio – 178 FW	F-16	3	1,987	525
Ohio – 180 FW	F-16	4	1,136	300
Oklahoma	F-16	4	379	100
Virginia – 192 FW	F-16	8	114	30
Texas -	F-16 C/D	16		
South Dakota – 114 FW	F-16 C-D	4	189-1892	50 – 500
Arizona – 162 FW	F-16, C-260	8	1,136	300
California – 144FW	F-16C, F-16D	8	1,324	350
Kulis ANG	H-60, C-130	10 minutes	757	200
Mississippi – 186 ARW	KC-135	72 man hours	34,067-41,638	9 – 11,000
Arizona – 161 ARW	KC-135E	2 days		
Illinois – 126 ARW	KC-135E	120-150 man hours	1,136	300
Maine – 101 ARW	KC-135E	8	946	250
New Jersey – 108 ARW	KC-135E	5 – 6	1,892	500
Pennsylvania – 171 AREFW	KC-135E	12		
Washington	KC-135E	4		
Kansas – 190 ARW	KC-135E, KC-135D	16		
Nebraska	KC-135R	6 – 10	2,271-3,785	600-1,000

* Unless otherwise indicated.