

**FINAL DRAFT**

**Project L-045H  
300 Area TEDF Technology  
Selection Engineering Report**

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## EXECUTIVE SUMMARY

Westinghouse Hanford Company (WHC) plans to build and operate a facility at the Hanford Site in Washington State to treat wastewater currently discharged to the 300 Area Process Trenches. Treatment of this wastewater, including chemical and physical processing as well as source control, is required to meet Tri-Party Agreement Milestone M-17-06, "Cease All Discharges to the 300 Area Process Trenches." Several source control measures have been implemented or planned, resulting in a significant reduction in flow of the wastewater. The reduced-flow wastewater will require additional treatment to satisfy the requirements of the WHC guidance document, Best Available Technology (economically achievable) Guidance Document for the Hanford Site. This guidance document combines the requirements of the Department of Energy, the Washington Department of Ecology, and the Environmental Protection Agency for treatment of hazardous wastewater.

Ebasco Services Incorporated (Ebasco) was requested by WHC to perform a technology selection study for the wastewater treatment system based on the WHC guidance document. The results of Ebasco's study are documented in this report. The Best Available Treatment, economically achievable system selected by Ebasco includes source control, a wastewater diversion and retention system, and treatment. The diversion and retention system will accommodate four days flow of off-normal wastewater. The treatment system will include co-precipitation and clarification for suspended solids and metals removal, organics removal through adsorption on granular activated carbon, and stand-by mixed-bed ion exchange. The ion exchange will be utilized whenever concentrations of inorganics are expected to exceed discharge criteria. This is anticipated to be primarily during treatment of wastewater diverted to the basins.

The selected alternative was considered to be the best of five options based on a set of evaluation criteria. These criteria address quality of the treated water; quantity and types of secondary waste produced; process flexibility, reliability, safety, and viability; capital and life-cycle costs; ease of maintenance; and overall cost-effectiveness. The other four alternatives utilized various combinations of filtration, activated carbon adsorption, ultraviolet oxidation, reverse osmosis, ion exchange, coagulation, and clarification.

The Rough Order-of-Magnitude capital cost of the overall waste treatment project (known as Project L-045H) is estimated at \$9.5 million assuming the selected alternative is used. Annual Operations and Maintenance costs are estimated at \$3 million, which includes the costs of disposing secondary wastes. The selected alternative removes 93% of the toxic materials removed by the most efficient alternative yet produces only 27% of the mass of secondary waste. The alternative is also considered to be much more reliable than the most efficient alternative, hence reducing the likelihood of off-normal operating conditions and the potential for discharges above permitted limits.

## 1.0 INTRODUCTION

This document describes a project, designated L-045H, which the U.S. Department of Energy (DOE) is currently implementing to provide a wastewater treatment facility at the Hanford Site.

### 1.1 SITE HISTORY

The Hanford Site is a DOE site occupying approximately 560 square miles of territory located near Richland in southeastern Washington. Approximately 14,000 Hanford personnel carry out programs of national and international scope and importance including defense programs, advanced nuclear reactor research, radioactive and hazardous waste management, energy conservation, and research in biomedicine, the environment, energy, molecular science, and life sciences.

DOE's Richland Operations Office (DOE-RL) provides overall management and administration of the Hanford Site. DOE-RL employs four contractors to implement the various Hanford programs. Westinghouse Hanford Company (WHC) provides operational administration, engineering development, and computer services. Kaiser Engineers Hanford Company provides architect/engineer and construction services for ongoing projects. Battelle Pacific Northwest Laboratory supports Hanford programs via basic and applied research activities. Hanford Environmental Health Foundation provides personnel protection services in the areas of occupational medicine, psychology, and environmental health services to DOE-RL and its Hanford Site contractors.

In 1943, the U.S. government established research, development, and production facilities at the Hanford Site to provide concentrated plutonium for use in nuclear weapons. Today, none of the nine reactors subsequently employed for plutonium production is in operation. However, the DOE maintains the capability to process and purify existing plutonium inventories utilizing associated facilities. Other significant Hanford Site activities include operation of the Fast Flux Test Facility (FFTF)--a research facility which supports development and testing of fuels and materials of construction for use in nuclear reactors of advanced design.

The Hanford Site contains four geographic areas in which activities involving radioactive materials and associated wastes are or were carried out:

- 100 Areas - Deactivated plutonium production reactors
- 200 Areas - Chemical processing and defense waste management
- 300 Area - Energy research and development
- 400 Area - Fast Flux Test Facility

### 1.2 PROJECT HISTORY

For more than 40 years, ongoing operations at the Hanford Site have taken advantage of Hanford's favorable geographic and climatologic characteristics such as isolation from

populated areas, minimal precipitation, and a deep water table. In addition, the soil's capacity for ion exchange and retention provided the rationale for discharging wastewater containing small concentrations of low-level radionuclides and stable chemical compounds into the local soil column. Recent DOE policy revisions mandate that the use of soil columns to treat and retain suspended or dissolved radionuclides from liquid waste streams be discontinued at the earliest practical date and replaced by systems and operating practices designed to treat and minimize wastewater streams. These policy revisions are being implemented through DOE Orders which are based on federal and state environmental regulations and/or interpretations.

The 300 Area Process Sewer, located in the 300 Area on the Hanford Site, collects wastewater from approximately 62 sources. This wastewater is discharged into two 1500 feet long percolation trenches. Current environmental statutes and policies dictate that this practice be discontinued at the earliest possible date in favor of treatment and disposal practices that satisfy applicable regulations. In May, 1989, an agreement reached among the U.S Department of Energy (DOE), the Environmental Protection Agency (EPA) and the Washington Department of Ecology (Ecology) prioritized environmental remediation activities at Hanford (DOE 1989). Included within this agreement (known as the Tri-Party Agreement) was Milestone M-17-06, "Cease All Discharges to the 300 Area Process Trenches."

DOE has assigned Westinghouse Hanford Company (WHC) the lead responsibility for meeting this milestone. In this role, WHC has developed an implementation plan for activities supporting this milestone through Fiscal Year 1991 (WHC 1990a). Longer-range activities are also scoped and preliminarily scheduled in this plan. These planned activities are aimed toward reducing the flow of waste streams and their contaminant loadings with the goal of minimizing the cost and complexity of a facility for treating the reduced-flow waste stream. The activities, which can be categorized as Source Control and Best Management Practices, include elimination of contributing waste streams through equipment upgrades, and implementing improved policy, training, and procedures regarding discharges to the 300 Area Process Sewer.

Although Source Control and Best Management Practices may be implemented without regulatory approval, actions regarding the selection, construction, and operation of a treatment system for the wastewater require regulatory approval and/or permits. One requirement for gaining the necessary approval/permit is a demonstration to the regulatory agencies that the best available technology will be utilized for preventing the degradation of surface water or ground water into which the treated wastewater will be discharged. The key regulatory programs that define the best technology are the Clean Water Act (CWA) and the Washington State Waste Discharge Permit (SWDP) program. These programs provide guidance on the regulatory meaning of best technology as it applies to effluent treatment systems.

The best technology requirements of the CWA will apply if the treated waters are discharged to the Columbia River. If so, a National Pollutant Discharge Elimination System (NPDES) permit will be required. Gaining this permit is contingent upon demonstrating that the Best Available Technology (BAT) is used to treat the wastewater. If the treated

wastewater is to be discharged to the soil column, the action must be permitted under the SWDP program. The treatment technology to be employed under the SWDP program requires selection based on consideration of All Known, Available and Reasonable methods of prevention, control and Treatment (AKART). The BAT and AKART processes are essentially equivalent.

To help ensure consistency in the selection of best technologies for Hanford wastewater treatment applications, WHC issued a guidance document (WHC 1988), *Best Available Technology (economically achievable) Guidance Document for the Hanford Site*. This guidance document served as the basis for a study to evaluate and select BAT for three waste streams originating within the 300 Area at the Hanford Site (Engineering Science 1989). The three waste streams included the 300 Area Process Sewer effluent, which was assumed to flow at a rate from 3785 to 6000 liters per minute (lpm) (1000 to 1600 gpm). Based on this flow rate and effluent characterization data available at the time, the recommended BAT included a retention system and standby treatment for any retained water found not to meet discharge criteria. All water that would meet discharge criteria (including water after treatment) was to be discharged to the Columbia River.

The City of Richland subsequently commissioned a study to use a similar BAT concept for a case in which the 300 Area Process Sewer wastewater was added to the city's sewer system (Beck 1990). The wastewater, commingled with city sewer water, would normally be discharged to the Columbia River after treatment in Richland's Publicly Owned Treatment Works (POTW). Sewer water not meeting the acceptance criteria for the POTW would be processed in a standby treatment system.

The high cost and uncertainties associated with these treatment options led WHC to conclude that reducing the waste source and improving knowledge of the waste would result in a less expensive treatment system and increase the probability of meeting discharge criteria. This conclusion supported efforts to further characterize the waste streams contributing to the 300 Area Process Sewer effluent. Based on the new characterization data and a preliminary evaluation of potential discharge criteria, WHC conceived a new treatment alternative. The treated water from this alternative process was to be discharged to the Columbia River. The process is described in WHC Functional Design Criteria and Conceptual Design reports (WHC 1990b and Kaiser 1990).

The estimated cost of the WHC treatment option, however, was considered to be unacceptably high. This concern led to an engineering review of the WHC option (Ebasco 1990). In its review report, Ebasco Services Incorporated (Ebasco) concluded that the cost estimate was likely high, although not excessively so. Ebasco also identified another option that may be less expensive. Ebasco cautioned that additional work regarding waste and river water characterization, identification of applicable water quality criteria, analysis of mixing zones, conducting treatability tests, and interaction with the regulatory agencies is required before selecting the treatment technology for the reduced-flow process sewer effluent. Some of that work has since been initiated.

## 2.0 WASTEWATER CHARACTERISTICS

Adequate characterization of the 300 Area process sewer effluent is required to provide a basis for making treatment and disposal decisions and to support the approval and permitting process. Complete characterization of the waste stream, however, is complicated by current and planned changes to the 300 Area Process Sewer effluent sources.

In support of a Best Management Practices (BMP) approach, WHC has instituted a program of physical and administrative source controls and waste minimization of the 300 Area Process Sewer effluent (WHC 1990a and WHC 1990c). Implementation of the planned flow reduction and source control tasks will reduce the process sewer flow rate from about 4920 lpm (1300 gpm) to about 757 lpm (200 gpm), reduce the concentration of some of the constituents of concern, such as silver, and reduce the potential for chemical spills to the process sewer. These tasks include elimination of overflow from emergency water supply storage tanks, replacement of some HVAC water chillers with air-cooled units, drain plugging, various process modifications, the use of closed loop cooling systems, and the implementation of additional administrative policy controls.

These activities are ongoing and will not be completed until shortly before the treatment facility is placed in operation. As a result, characterization data for the process sewer effluent must be estimated from current chemical analyses after accounting for the effects of the proposed source controls and waste minimization efforts.

The projected concentrations of constituents of the process sewer effluent are presented in Table 2-1. These concentrations were calculated by WHC assuming a sewer flow rate of 1135 lpm (300 gpm). Ebasco had previously assessed the characterization approach used by WHC and found it to be logical and thorough given the data available (Ebasco 1990). Specific suggestions for further characterization were also identified.

Table 2-1. Projected Process Wastewater Concentration

<u>Organic Compounds (ppb)</u>		<u>Inorganic Compounds (ppb)</u>	
Halogenated Hydrocarbons (HH)	9	Aluminum	350
Purgable Org. Halides (POX)	6	Ammonia	400
Total Carbon	14000	Arsenic	10
Total Organic Carbon (TOC)	6000	Barium	60
Total Organic Halides (TOX)	200	Beryllium	30
Acetone	70	Boron	25
Bisethanoethanedithiol	1	Bromide	4
Bis(ethylhexyl) phthalate	80	Cadmium	10
2-Butoxyethanol	1	Calcium	30000
2-(2-butoxy ethoxy) ethanol	100	Chloride	60000
Chlorodifluoromethane	20	Chromium	10
Chloroform	40	Copper	80
1,1-Dichloroethane	40	Cyanide	50
Dichlorodifluoromethane	3	Fluoride	200
Ethyl alcohol	3	Iron	600
Methyl ethyl ketone	5	Lead	60
Methylene chloride	4	Lithium	30
m-Xylene	1	Magnesium	5000
o,p-Xylene	1	Manganese	60
2-Propanol	4	Mercury	3
Tetrachloroethylene	10	Nickel	60
Toluene	2	Nitrate	6000
1,1,1-Trichloroethane	10	Nitrite	400
Trichloroethene	0.4	Phosphate	1000
Trichloromonofluoromethane	1	Potassium	1000
Unknown	50	Selenium	6
Unknown aliphatic HC	3	Silicon	3000
Unknown amide	2	Silver	20
Unknown amine	10	Sodium	40000
Unknown aromatic HC	4	Strontium	100
Unknown fatty acid	30	Sulfate	30000
Unknown fatty acid ester	1	Sulfide	100
Unknown PAH	40	Tin	100
		Titanium	7
		Uranium	10
		Vanadium	8
		Zinc	150
		<u>Miscellaneous Parameters</u>	
<u>Radionuclides (pCi/L)</u>		Alkalinity (ppb)	60000
Alpha Activity	9	Coliform (# per 100 mL)	230
Beta Activity	40	Conductivity-field (uS)	250
Am-241	0.4	pH-field	9
Co-60	1	Suspended Solids (ppb)	9000
H-3 (tritium)	400	Total Dissolved Solids (ppb)	120000
Pu-239/240	0.2		
Radium Total	0.2		
Ru-106	4		
Sr-90	1		
Uranium Total	8		

### 3.0 GUIDANCE FOR SELECTION OF TREATMENT TECHNOLOGY

The DOE has established a procedure for determining the Best Available Technology (BAT) to be utilized in treating wastewater streams at the Hanford Site (WHC 1988). As applied to any specific stream or combination of streams, the procedure incorporates the flexibility necessary to support determination of BAT without limitation as to the variety or concentrations of individual contaminant species.

The Washington State Department of Ecology (Ecology) has determined that all known, available, and reasonable treatment (AKART) must also be applied in order for Ecology to certify an NPDES permit issued by EPA. In general, the AKART process is similar to the BAT determination process, with the major difference being that Ecology may require more stringent treatment. For purposes of selecting treatment technologies, as discussed below, it has been assumed that Ecology's AKART selection process is included as an integral element of the BAT determination process.

Section 3.1 provides a brief summary of the BAT determination procedure. Section 3.2 describes the steps taken in applying the procedure to identify, compare, and select process technologies for use in the L-045H treatment facility.

#### 3.1 OVERVIEW OF THE BAT DETERMINATION PROCEDURE

Many of the Hanford wastewater streams are unique in terms of the combination of contaminant species and associated concentrations. Hence, the approach to selection of BAT for treatment of those streams must include consideration and evaluation of a large number of related components.

In general, federal and state regulations do not explicitly identify effluent treatment levels necessary for Hanford wastewater streams. Regulations do establish ambient water quality criteria, in receiving surface waters, for assessing treatment systems and treated effluent levels. The water quality criteria can be used to identify parameters of interest in a waste stream that may adversely affect aquatic species and humans using the surface water. The treatment technology identification process must include consideration of the ability of candidate BAT systems to effectively treat the parameters of interest.

For certain industrial categories, federal and state agencies provide guidance for selection of BAT for treating certain liquid waste streams, however, that guidance does not apply directly to Hanford streams. Thus, the selection of BAT for treating a given Hanford stream requires identification and evaluation of treatment methods or technologies which are either being applied successfully, or have been approved for application, in treating streams which exhibit contaminant characteristics similar to those of the Hanford stream.

The resulting BAT selection process relies heavily on the existence of treatment systems that can be adapted for use at Hanford. However, the adaptation process is complicated by the fact that Hanford streams typically display unique contaminant characteristics. For example, various industries have used a wide range of technologies to successfully treat organic contaminants. However, the dissolved solids commonly found in

Hanford streams in combination with organic contaminants preclude simple application or adaptation of those technologies. Furthermore, the removal efficiencies of certain technologies that are effective in treating a given contaminant are often reduced by the presence of other contaminants in the stream. Therefore, treatment of a typical Hanford wastewater stream requires development of a system consisting of a carefully considered combination of technologies to be applied to the stream in the proper sequence.

For streams where no applicable effluent limits exist, an important, additional constraint in BAT selection is the case-by-case application by regulators of a technique known as Best Professional Judgement (BPJ) to establish effluent limitations. According to the EPA, BPJ is "the highest quality technical opinion developed by a permit writer after consideration of all reasonably available and pertinent data or information." Existing regulatory criteria identify key BPJ considerations including engineering feasibilities, environmental objectives, and economic realities. The Clean Water Act and recent EPA training manuals provide regulators with additional guidance for striking a balance among competing considerations, for ensuring consistency in application among similar cases, and for avoiding arbitrary decisions.

After considering the complexities described above, the DOE organized the BAT selection process into a series of five steps which can be applied, in sequence, to determine BAT for a given wastewater stream. The resulting procedure is illustrated in Figure 3-1. The first step involves acquisition and correlation of stream-specific data. This step includes determination of applicable or relevant regulatory standards, such as ambient surface water quality criteria, which may be used to set effluent limits for specific waste stream parameters. Any one of the four succeeding steps can result in determination of BAT. Thus, steps two through four are applied in sequence, but only up to the point at which a determination of BAT is reached. Sections 3.1.1 through 3.1.5 provide summaries for the five individual steps.

### 3.1.1 Wastewater Characterization

The first step in the BAT procedure is to characterize the wastewater stream. Characterization consists of identifying and quantifying the physical and chemical parameters of the stream as well as quantifying the flow characteristics of the stream.

Comparison of the characterization data with applicable or relevant effluent limits provides an indication of the extent of treatment required, if any, for specific parameters. Where treatment is indicated, the categories and concentrations of those parameters guide the subsequent search for a treatment process or a series of treatment processes which can provide the necessary reductions in concentration.

The stream flow characteristics determine the capacity and configuration of any equipment associated with the treatment concept. The maximum design flow rate, combined with any provisions for standby equipment, establishes the total capacity requirement. For certain process technologies, a minimum design flow rate or typical operating procedure dictates that the total capacity be subdivided into parallel modules to obtain effective treatment during periods of reduced flow or to accommodate equipment maintenance. In

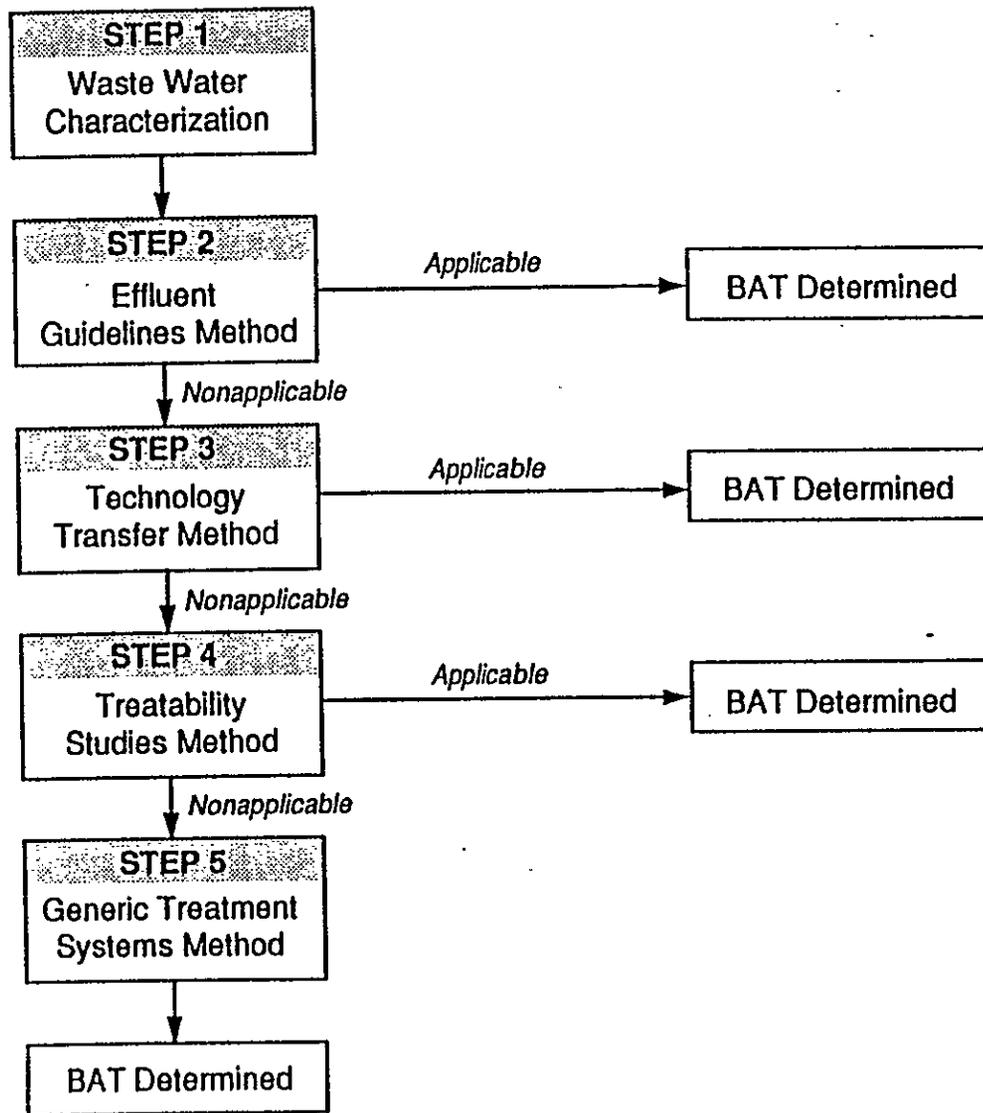


Figure 3-1. Best Available Technology (BAT) determination process.

addition, many systems are designed to treat a stream comprised of a combination of streams having independently variable flow rates and/or contaminant concentrations. Those systems often include a means of damping (or equalizing) fluctuations in flow and concentration in order to sustain consistent and effective treatment.

### **3.1.2 Effluent Guidelines Method**

BAT may be determined in step two based on identification and evaluation of relevant or applicable effluent guidelines. Federal and state effluent guidelines establish BAT for treatment of certain industrial waste streams. Those guidelines could include limits for specific chemical compounds or for radiation exposure. In cases for which guidelines exist and for which an industrial waste stream is sufficiently similar to a Hanford waste stream, it may be appropriate to apply the effluent guidelines method. Evaluation of process technologies for these waste streams in similar applications can provide direction for determining BAT for the Hanford treatment application.

### **3.1.3 Technology Transfer Method**

Step three can determine BAT by identifying technology which can be duplicated or adapted (i.e. transferred) from systems that are either operating or that have been approved for design and construction in other, similar applications. It entails surveying potentially comparable wastewater streams and associated BAT treatment systems and then assessing the degree of similarity with the Hanford stream under consideration. If one or more applications are identified as being sufficiently comparable to the Hanford requirement in terms of influent characteristics and desired effluent quality, then it may be possible to apply similar treatment technologies and effluent limitations to the Hanford stream as BAT.

### **3.1.4 Treatability Studies Method**

Failure to determine BAT by application of steps two or three, as described above, leads to step four. Step four involves performing a series of treatability studies, the results of which may suggest several treatment options which could be applied as BAT for the Hanford stream. This method involves identifying one or more systems which have been proven effective in treating wastewater streams similar to the Hanford stream. It differs from step three in that it considers a wider array of applications in which influent characteristics and desired effluent quality are similar to those of the Hanford stream, but not sufficiently comparable to support direct technology transfer.

### **3.1.5 Generic Treatment Systems Method**

Step five is the generic treatment systems method. It is a procedure for determining BAT in cases where there is little or no relevant data available regarding treatment of similar wastewater streams. The procedure begins with identification and evaluation of generic control methods. If necessary, it continues with identification and evaluation of alternatives for treatment of specific stream parameters. Acceptable alternatives, individually or in combination with others, are used to formulate a group of candidate systems, each of which exhibits reasonable expectation for successful treatment. The procedure concludes with

selection of one candidate system after a comparison based on selected site- and stream-specific criteria.

### **3.2 APPLICATION OF THE BAT PROCEDURE TO L-045H**

The following sections describe the steps involved with applying the procedure described above to determine BAT for treating the L-045H wastewater stream. Sections 3.2.1 through 3.2.5 relate to application of steps 1 through 5 of the procedure, respectively.

#### **3.2.1 L-045H Wastewater Characterization**

The first step in the BAT selection procedure involved assembling all relevant wastewater characterization data. Results of that effort, as applied to the L-045H wastewater, were presented in Section 2.

#### **3.2.2 Effluent Guidelines Method for Determining BAT**

The first of the four methods relies on federal and state guidelines for effluent limits in a wastewater stream. The following sections review several potentially applicable or relevant effluent quality and water quality guidelines and standards.

##### **3.2.2.1 Clean Water Act (CWA)**

Effluent limits have been set under the CWA for 34 industrial source categories. None of these source categories is applicable to Project L-045H.

##### **3.2.2.2 Radiation Exposure Limits**

Radiation protection standards by the DOE, EPA, and NRC for off-site or uncontrolled areas may be considered analogous to water quality standards within the National Pollutant Discharge Elimination System (NPDES) program. These standards set upper bounds on the acceptable consequences of a discharge, with these bounds expressed in terms of risk, rather than pollutant concentrations.

The DOE has established requirements for the disposal of wastewater on the Hanford Site. These requirements are contained in a set of orders that require protection of public health and safety and are intended to control, to the extent possible, adverse impacts to the environment. Liquid disposal practices on the Hanford Site are conducted in accordance with these requirements. As such, the application of BAT to the wastewater streams may result in an additional level of control, as well as contribute to the overall As Low As Reasonably Achievable (ALARA) program at the Hanford Site.

The EPA limits for total annual radiation doses to members of the public are 25 millirem per year (mrem/yr) to the whole body, 75 mrem/yr to the thyroid, and 25 mrem/yr to any other organ (40 CFR Part 190 and Part 191 Subpart A). The limits specified in 40 CFR Part 190, for commercial electric power generation, apply to the cumulative effects of all activities that are part of a nuclear fuel cycle. The limits specified in 40 CFR Part 191

are for activities related to the management and disposal of spent nuclear fuel, high-level, and transuranic radioactive wastes at any facility regulated by the NRC; or at DOE disposal sites for transuranic wastes, spent fuel, or high-level wastes. Similar limits for low-level waste may be included in future 40 CFR Part 193 regulations.

The NRC regulation 10 CFR Part 50 sets licensing standards for nuclear facilities, including some reactors operated to produce primarily uranium and plutonium, and some separation facilities. Although Hanford Site facilities are exempt from 10 CFR Part 50, these standards provide guidance on design objectives and limiting conditions for radiation releases.

Standards established for new commercial reactors under the Atomic Energy Act (AEA) may be equal to or more stringent than the standards that may be established using a BAT determination. In fact, 10 CFR Part 50 requires that these new facilities be designed and operated to comply with ALARA, as designated by 10 CFR Part 50, Appendix A numerical standards. These standards limit off-site doses from each reactor to not more than 3 mrem/yr to the whole body and 10 mrem/yr to any organ, and additionally require use of all controls that can reduce exposures within a 50-mile radius at a cost of \$1,000/man rem or less. Appendix A of 10 CFR Part 50 further advises that the maximum dose in unrestricted areas due to all liquid effluents from all reactors at a site should not exceed 5 mrem/yr, and that radiation releases in liquid effluents from each reactor should not exceed 5 curies per year (Ci/yr). The standards are set without regard to the types of water quality and use evaluations that are relevant under the CWA.

Radiation standards alone are not adequate for BAT determination in Project L-045H due to the presence of constituents of concern other than radionuclides.

### **3.2.2.3 Hazardous Waste Standards**

Ecology and EPA have promulgated standards related to hazardous waste that may affect the limits to be established on discharges from Project L-045H. State standards for hazardous waste are promulgated pursuant to Chapter 70.105 of the Revised Code of Washington (RCW), Hazardous Waste Management Act. Federal standards for hazardous waste are promulgated under the 1976 Resource Conservation and Recovery Act (RCRA) and the 1984 Hazardous and Solid Waste Amendments (HSWA).

These standards are typically applied to waste streams that are or may be hazardous waste, or that may be the result of processing hazardous wastes. However, the agencies may utilize these standards to ensure that the treated L-045H effluent will not be a hazardous waste, or will not be causing circumstances in the environment that could become subject to hazardous waste regulation in the future.

#### Hazardous Waste Designation

Designation limits for determining if a waste is hazardous or not are set forth in Washington Administrative Code (WAC) 173-303-080 through 173-303-103. The federal counterpart is 40 CFR Part 261. In addition to various lists of hazardous wastes, these

regulations can designate hazardous waste on the basis of the concentration of hazardous constituents present in the waste. The designation standards include:

- The Toxicity Characteristic (TC);
- Acute toxicity;
- Halogenated hydrocarbon (HH) concentrations;
- Polycyclic aromatic hydrocarbon (PAH) concentrations; and
- Carcinogen concentrations.

Toxic Characteristic (TC) limits are adopted under Chapter 173-303-090 WAC and 40 CFR 261.24. These standards set maximum concentrations for certain chemicals that, if exceeded in a waste stream, cause the waste stream to be designated a hazardous waste. Depending on the concentrations of TC compounds in the treated effluent from Project L-045H, the effluent may be a hazardous waste. However, most of the TC limits (except for pesticides, which have not been identified in the L-045H waste stream) are in excess of 100 parts per billion (ppb). Since the anticipated Project L-045H treatment system is designed to achieve concentrations of these compounds in the low (e.g., less than 10) ppb range, it is unlikely that the treated L-045H effluent would be designated hazardous waste for reasons of TC.

Acute toxicity designation is unique to Washington's regulations, and is adopted under Chapters 173-303-084 WAC and 173-303-101 WAC. If a compound or mixture of compounds is present in a waste stream at sufficient concentrations to be acutely toxic to certain animal species, then the waste stream is designated a hazardous waste. Since the acute toxicity of individual compounds can vary widely and there are no fixed concentration limits, it is not possible to identify exact acute toxicity numerical criteria for constituents in the Project L-045H treated effluent. It may be necessary to perform toxicity calculations or tests on surrogate waste streams or on actual effluent after the system becomes operational. However, based on expected constituents and concentrations, it is unlikely that the treated L-045H effluent would be designated for acute toxicity.

The HH, PAH, and carcinogen designations are unique to Washington's regulations. The associated standards are set forth in Chapters 173-303-084 WAC, 173-303-102 WAC, and 173-303-103 WAC. The presence of HH, PAH, or carcinogen compounds will generally not result in a hazardous waste designation unless a concentration of 100 to 10,000 parts per million (ppm) of these compounds is exceeded. The anticipated Project L-045H treatment system is designed to achieve concentrations of these compounds in the low parts per billion (ppb) range. Thus HH, PAH, and carcinogen compounds in the treated L-045H effluent are not expected to cause the effluent to be designated a hazardous waste.

#### Land Disposal Restrictions

EPA has adopted regulations that restrict certain wastes from management in land disposal units (e.g., landfills or surface impoundments). These land disposal restrictions (LDRs) are promulgated in 40 CFR Part 268. Although Project L-045H currently anticipates direct discharge to the Columbia River, one potential option that may still be considered

includes discharge to ground. In this case, the LDR's may be applied by the agencies to limit constituent concentrations in the treated effluent.

Ecology has not yet incorporated the federal LDRs in state regulations. Many of the LDRs are based on allowable concentrations of hazardous constituents in proscribed hazardous wastes. If analyses show that allowable concentrations are not exceeded, then the waste is not prohibited from land disposal. This does not mean that the waste is no longer designated as hazardous waste, only that it is acceptable for management in RCRA-permitted land disposal units.

Numerical limits established for the LDRs were derived primarily from EPA data indicating the level of treatability that can be achieved for various hazardous waste streams using demonstrated and generally available treatment technologies. Thus, the LDRs are often specific to the waste type and treatment methods evaluated by EPA. It is not known at this time if the Process Sewer wastewater will be a hazardous waste. If not, the LDRs are not legally applicable to discharges of the effluent to ground. However, the agencies may consider the LDRs to represent compound concentration limits that can generally be achieved through the application of available and established management practices. Thus, LDR treatment technologies may be considered as potential BAT by the regulatory agencies.

#### Corrective Action Levels

On July 27, 1990, EPA proposed 40 CFR Part 264 Subpart S regulations related to performing corrective actions at solid waste management units. Proposed 40 CFR 264.521(a)(2) identifies various criteria for determining when corrective actions should be considered necessary. Numerical concentrations were developed by EPA for many hazardous constituents and issued for comment. In addition to being compound-specific, the concentrations are also presented by media (i.e., air, water, or soil), thus different action levels are identified depending on the environmental media affected by the compounds.

In general, EPA has proposed to use these criteria as a basis for requiring corrective actions (e.g., soil remediation) to be undertaken at hazardous waste facility sites. Although the corrective action standards are only proposed at this time, they are expected to be promulgated by the time that Project L-045H begins to operate. At this time, Ecology has not given any indication when equivalent state regulations may be proposed. Since the corrective action levels are derived from various health and environmental risk-based models, the agencies may use these levels for evaluating effluent limits for Project L-045H.

#### **3.2.2.4 Drinking Water Standards**

The Washington Department of Health (Health) and EPA have promulgated regulations to protect the quality of water supplied for human use and consumption. Generally referred to as drinking water standards, they are derived from state authority under Chapter 43.20 RCW, State Board of Health Act, and from federal authority under the Safe Drinking Water Act (SDWA). The drinking water standards are directed primarily at persons who provide public water supplies. However, because the standards are based on human health

- Maximum contaminant levels (MCLs) established for toxics and carcinogens. MCLs are to be set at non-toxic effect levels, and as close as possible to MCLGs, with some allowance for economic and technical factors; and
- Secondary maximum contaminant levels (SMCLs) established primarily on the basis of secondary water effects such as color, odor, and taste. SMCLs are generally set for compounds that are not considered to be toxic or carcinogenic to humans.

Until recently, drinking water standards existed for only about a dozen compounds. Changes to federal regulations (soon to be mirrored in state regulations) have added nearly fifty additional compounds; many more compounds are projected for addition over the next several years. Both Ecology and EPA utilize the drinking water standards to determine potential for adverse impacts on ground water and surface water. Exceedance of the drinking water standards has been, and is likely to remain, a standard basis for identifying environmental concerns.

The drinking water standards would likely be considered relevant criteria by EPA and Ecology for purposes of setting Project L-045H discharge limits. That relevance could apply to both river and soil discharge options. With the exception of cadmium, lead, and mercury, untreated L-045H wastewater meets the current drinking water standards; all constituents in the effluent after treatment are expected to meet these standards.

### 3.2.2.5 Ambient Surface Water Quality Standards

Ecology and EPA have identified ambient surface water criteria designed to prevent adverse effects to aquatic organisms living in the water, and to humans who may be consuming aquatic organisms. Ecology has promulgated surface water regulations pursuant to Chapter 90.48 RCW, Water Pollution Control Act (WPCA). EPA has established water quality criteria (although not yet promulgated in regulations) pursuant to authority under the CWA. The focus of these standards and criteria is to define ambient levels of chemical concentrations that are not expected to pose adverse effects if present in the aquatic environment.

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Human consumption criteria may also reflect certain factors related to the tendency of some compounds (typically carcinogens) to accumulate and/or bioconcentrate in aquatic species prior to consumption. Thus, EPA's Gold Book lists a range of criteria reflecting 1 in 100,000, 1 in 1,000,000, and 1 in 10,000,000 incremental human cancer risk from consuming affected aquatic organisms, or organisms and water. The standard agency practice is to strive for the lowest possible risk level, and except in rare instances, to accept no greater risk than 1 in 1,000,000.

#### Anticipated Amendments to State Standards

Draft copies of amendments to the state surface water standards are currently being circulated for public review. Ecology is expected to be adding many new compounds to the

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list of already regulated chemicals. In addition to the EPA Gold Book criteria, Ecology is expected to incorporate some of the risk-based approach used to set drinking water standards, thus developing criteria based on human consumption of the surface water as a drinking water source. In summary, Ecology and EPA are likely to consider the relevant surface water standards in setting discharge limits for treated effluent from Project L-045H.

### 3.2.2.6 Ground Water Quality Standards

Ecology recently adopted regulations pursuant to the state WPCA setting forth standards for protection of ground water. The purpose of these standards is to establish criteria that must not be exceeded in order to protect existing and potential future uses of ground water. The presumption by Ecology is that ground water, other than naturally contaminated or nonusable waters (e.g., perched and seasonal, brackish), should be reserved and protected for use as drinking water. Such usability will be ensured if the ground water standards are met. Although Project L-045H currently anticipates discharge to the Columbia River, one potential option that may still be considered includes discharge to ground. In addition, Ecology has expressed an opinion that, because the groundwater standards are derived from human health risk-based models, the standards are valid even for surface waters. Thus, the agencies may apply the groundwater standards when setting effluent limits for Project L-045H.

Ecology's ground water standards are promulgated in Chapter 173-200 WAC, "Water Quality Standards for Ground Waters of the State of Washington." These standards establish both numeric and narrative criteria. Numeric criteria are derived from federal and state MCLGs, MCLs, and SMCLs. In addition, for carcinogens, Ecology has adopted a risk-based equation and standard exposure assumptions for calculating a 1 in 1,000,000 incremental human cancer risk from consumption of affected water. The numeric criteria are considered by Ecology to be maximum allowable levels after all other options have been exhausted. If lower levels can be achieved through more aggressive treatment or management options, then Ecology will require such options. Discharges that could affect ground water and thus cannot ensure the standards will be met, will generally not be allowed by Ecology unless some overriding public interest will be served.

In addition to the numeric criteria, Ecology has general narrative criteria promoting an "antidegradation policy." In many cases, it will not be sufficient to show that discharges entering an aquifer will not exceed ground water standards. The antidegradation policy will require a showing that all available and reasonable efforts have been undertaken to avoid degrading the ground water quality. In order to show that ground water quality will not be degraded, or that any degradation will be minimized as much as possible, current and projected ground water conditions may have to be established. Thus, background (i.e., uninfluenced by anthropogenic activities) ground water quality may be used by Ecology as a criterion for limiting effluent discharges.

### 3.2.2.7 Summary

In summary, none of the effluent guidelines and water quality standards described above provide an adequate basis for identifying treatment technologies and establishing BAT.

The various standards and criteria do, however, offer guidance in the development and evaluation of alternatives in the subsequent BAT selection steps. Table 3-1 presents specific numerical limits which could be derived via application of the guidelines and criteria discussed above. In all cases, the limits indicated are the most restrictive limits identified. Values are also shown for the projected influent levels expected for Project L-045H and the resulting Decontamination Factors (DFs) required to meet the most restrictive targets. Comparison of the most restrictive targets for the effluent with the influent levels indicates that the L-045H treatment system will likely be required to reduce concentrations of the following influent constituents:

- Suspended solids
- Organics
- Dissolved solids

The 20 specific constituents or parameters that have a DF greater than 1, and thus exceed the most restrictive target, are shown in Table 3.1.

### 3.2.3 Technology Transfer Method

Determination of BAT by the technology transfer method requires the identification of streams that are being successfully treated at other sites and which are nearly identical to the L-045H wastewater. If one or more such treatment applications are identified, it is likely that similar treatment technologies may be used and that the established effluent limitations may be adapted for L-045H. Differing state regulations, however, must be accounted for when utilizing technology transfer for determination of BAT.

The wastewater to be treated by the L-045H treatment system, as described in Section 2, consists of process wastewater from 62 sources. This waste stream has unique site-specific characteristics. No waste streams were identified which were sufficiently similar to the L-045H effluent to allow for direct determination of BAT according to the Technology Transfer Method.

It is useful, however, to review technologies used at the DOE Savannah River Site and at Oak Ridge National Laboratory for treatment of wastewater streams similar to those targeted by Project L-045H. At the Savannah River Site, the F/H Area Effluent Treatment Facility (ETF) treats a process condensate stream with some characteristics similar to L-045H. Contaminants in the stream include anionic and cationic metals, radionuclides, and organics. The concentrations of heavy metal contaminants are of the same order of magnitude. The ETF feed stream however consists mainly of sodium nitrate at concentrations orders of magnitude above those in the 300 Area process water.

Table 3-1. Treatment Targets

Constituent	Concentration	Most Restrictive Target	Required DF
<u>Organic Compounds (ppb)</u>			
Halogenated Hydrocarbons (HH)	9	1100	
Purgable Org. Halides (POX)	6		
Total Carbon	14000		
Total Organic Carbon (TOC)	6000		
Total Organic Halides (TOX)	200		
Acetone	70	800	
Bisethanoethanedithiol	1		
Bis(ethylhexyl) phthalate	80	3	27
2-Butoxyethanol	1		
2-(2-butoxy ethoxy) ethanol	100		
Chlorodifluoromethane	20		
Chloroform	40	0.19	210
1,1-Dichlorethane	40	1	40
Dichlorodifluoromethane	3		
Ethyl alcohol	3		
Methyl ethyl ketone	5	400	
Methylene chloride	4	5	
m-Xylene	1		
o-,p-Xylene	1		
2-Propanol	4		
Tetrachloroethylene	10	0.8	13
Toluene	2	2000	
1,1,1-Trichloroethane	10	200	
Trichloroethene	0.4	3	
Trichloromonofluoromethane	1		
Unknown	50		
Unknown aliphatic HC	3		
Unknown amide	2		
Unknown amine	10		
Unknown aromatic HC	4		
Unknown fatty acid	30		
Unknown fatty acid ester	1		
Unknown PAH	40	0.0028	14000

Table 3-1. Treatment Targets (cont.)

Constituent	Concentration	Most Restrictive Target	Required DF
<u>Inorganic Compounds (ppb)</u>			
Aluminum	350	50	7
Ammonia	400	2100	
Arsenic	10	0.0022	4500
Barium	60	1000	
Beryllium	30	0.0068	4400
Boron	25		
Bromide	4		
Cadmium	10	1.1	9.1
Calcium	30000		
Chloride	60000	250000	
Chromium	10	50	
Copper	80	12	6.7
Cyanide	50	5.2	9.6
Fluoride	200	4000	
Iron	600	300	2
Lead	60	3.2	19
Lithium	30		
Magnesium	5000		
Manganese	60	50	1.2
Mercury	3	0.012	250
Nickel	60	13.4	4.5
Nitrate	6000	10000	
Nitrite	400	487	
Phosphate	1000		
Potassium	1000		
Selenium	6	10	
Silicon	3000		
Silver	20	0.12	170
Sodium	40000		
Strontium	100		
Sulfate	30000	250000	
Sulfide	100	2	50
Tin	100		
Titanium	7		
Uranium	10		
Vanadium	8		
Zinc	150	110	1.4

Table 3-1. Treatment Targets (cont.)

Constituent	Concentration	Most Restrictive Target	Required DF
<u>Radionuclides (pCi/L)</u>			
Alpha Activity	9	15	2
Beta Activity	40	20	
Am-241	0.4	4	
Co-60	1	200	
H-3 (tritium)	400	20000	
Pu-239/240	0.2	40	
Radium Total	0.2	5	
Ru-106	4	300	
Sr-90	1	8	
Uranium Total	8		
<u>Miscellaneous Parameters</u>			
Alkalinity (ppb)	60000		
Coliform (# per 100 ml)	230		
Conductivity (uS)	250		
pH	9	6.5-8.5	
Suspended Solids (ppb)	9000		
Temperature (celsius)	24		
Total Dissolved Solids (ppb)	120000		

The ETF effluent consistently meets NPDES permit limits as established by the South Carolina Department of Health and Environmental Control. Those limits encompass biochemical oxygen demand, total suspended solids, ammonia, oil and grease, chromium, copper, lead, mercury, zinc, and stream pH.

After flow equalization, the ETF process, as shown in Figure 3-2, begins with pH adjustment. It continues with submicron filtration to remove suspended solids, ion exchange to remove mercury, granular activated carbon adsorption to remove organics, reverse osmosis for concentration of dissolved solids, further ion exchange to remove residual metallic ions, and finally, evaporation to concentrate the solids for disposal (Ryan and Stimson 1984). The ETF is designed to treat a stream consisting primarily of evaporator condensate. The system has a maximum design capacity of 1135 lpm (300 gpm). Two waste treatment systems are used at the Oak Ridge National Laboratories for treatment of process wastewater (Robinson 1990). Radioactive wastewater is treated at the Process Waste Treatment Plant (PWTP). Nonradioactive wastewater is treated at the Nonradiological Wastewater Treatment Plant (NRWTP). For the two systems, discharge limits for nonradioactive constituents are set by an NPDES permit, while radionuclide discharges are limited by Derived Concentration Guidelines as established by DOE Order 5400.5.

Chemical precipitation, filtration, and ion exchange are used at the PWTP. Calcium, magnesium, and some of the radionuclides are removed in a clarifier by adjusting the pH to 11.4 followed by sludge dewatering in a filter press. Ion exchange is then used for removal of remaining radionuclides.

Nonradioactive waste water and effluent from the PWTP is sent to the NRWTP for removal of metals and organics. The NRWTP uses chemical precipitation for removal of heavy metals, air stripping for removal of volatile organics, and activated carbon adsorption for removal of nonvolatile organics.

The typical NRWTP process wastewater contains cations, anions, and heavy metals at concentrations, in general, very similar to that of the 300 Area process water. The major exception to this is that the 300 Area process water contains higher concentrations of sodium chloride and an order of magnitude more iron.

The wastewater streams and treatment systems discussed above are similar enough to L-045H wastewater to suggest technologies for use in the L-045H treatment system. Still, they are sufficiently different in chemical and radiological contaminant characteristics to preclude direct application of the technology transfer method. Therefore, essentially all of the technologies employed in the systems described above were included in the screening and evaluation of technologies for use in the L-045H treatment facility via the generic treatment system method described below in Section 3.2.5.

#### 3.2.4 Treatability Studies Method

The treatability studies method may be used to identify BAT when neither effluent guidelines nor technology transfer is applicable. This method utilizes treatability study results to suggest control options which may be BAT. Use of this method is possible if

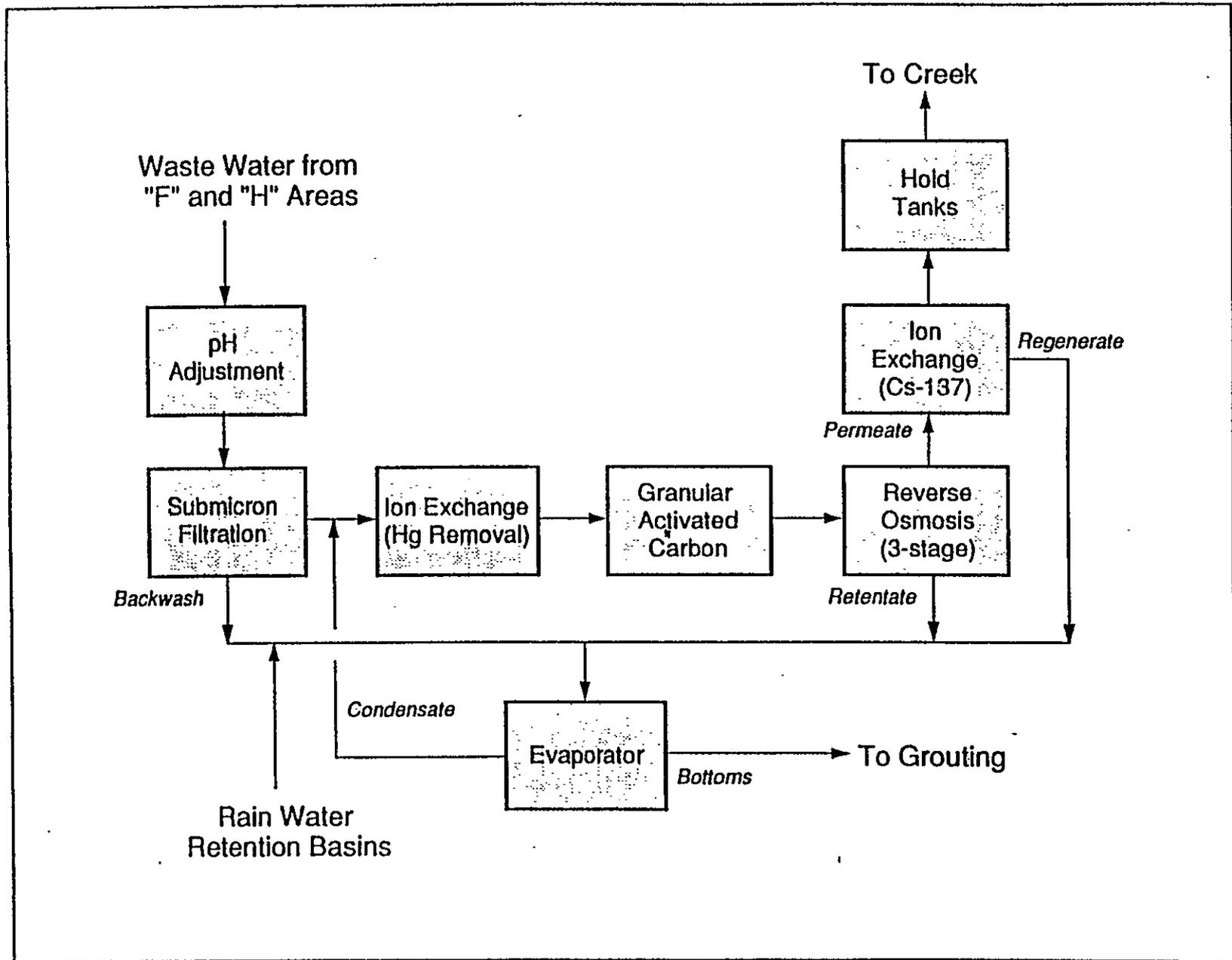


Figure 3-2. Simplified flow diagram of Savannah River Effluent Treatment Facility.

either one of the two following conditions are met:

- A level of treated effluent quality has been accepted for discharge by regulatory agencies; or
- Current control practices establish a pattern of control efficiency (i.e., percentage removal) or treatment intensity (i.e., number and type of treatment steps).

The first of these conditions does not apply as explained in Section 3.2.3 because no existing wastewater is sufficiently similar to L-045H wastewater. While there is no definite trend in control efforts for waste stream types similar to L-045H, the treatment systems at Savannah River and Oak Ridge do provide a basis for further development using the generic treatment system method described below.

### 3.2.5 Generic Treatment Systems Method

As described in the preceding sections, technology transfer and treatability studies were not appropriate methods for determining BAT for treatment of L-045H wastewater. Therefore, it was necessary to apply the generic treatment systems method as outlined in Section 3.1.5 above. Figure 3-3 illustrates the steps taken in applying this method to L-045H.

The WQC for protection of human health and freshwater aquatic species were discussed in section 3.2.2.5. The chronic WQC are used to calculate toxic weighting factors (TWF) which are shown in Table 3-2. The TWFs are equivalency factors, standardized to copper, which reflect the relative toxicity of a given compound. They are used to assess the cost-effectiveness of toxic pollutant removal. These factors reflect the toxic potential of pollutants so that effectiveness is not simply a function of total mass removed. They are calculated from the given WQC using the following equation as identified in the Hanford BAT Guidance document (WHC 1988):

$$TWF = \frac{5.6}{WQC_{hh}} + \frac{5.6}{WQC_{chr}} \quad (Eqn. 1)$$

where  $WQC_{hh}$  and  $WQC_{chr}$  are the human health WQC and fresh water species chronic exposure WQC.

The TWFs for the radionuclides are calculated from the Washington State definition of deleterious concentrations of radionuclides in surface waters. This definition identifies deleterious concentrations as those which exceed 1/100 of the value given in Appendix B, 10 CFR Part 20. These concentrations are converted from uCi/L to ug/L and applied to the above equation the same way as the WQC.

Estimates of toxic mass removed are used in the Generic Treatment Systems method to compare treatment alternatives. The incremental cost of additional toxic mass removal gives a measure of cost effectiveness. An upper threshold for cost effectiveness is considered to be \$200 per toxic equivalent kilogram (\$90/lb).

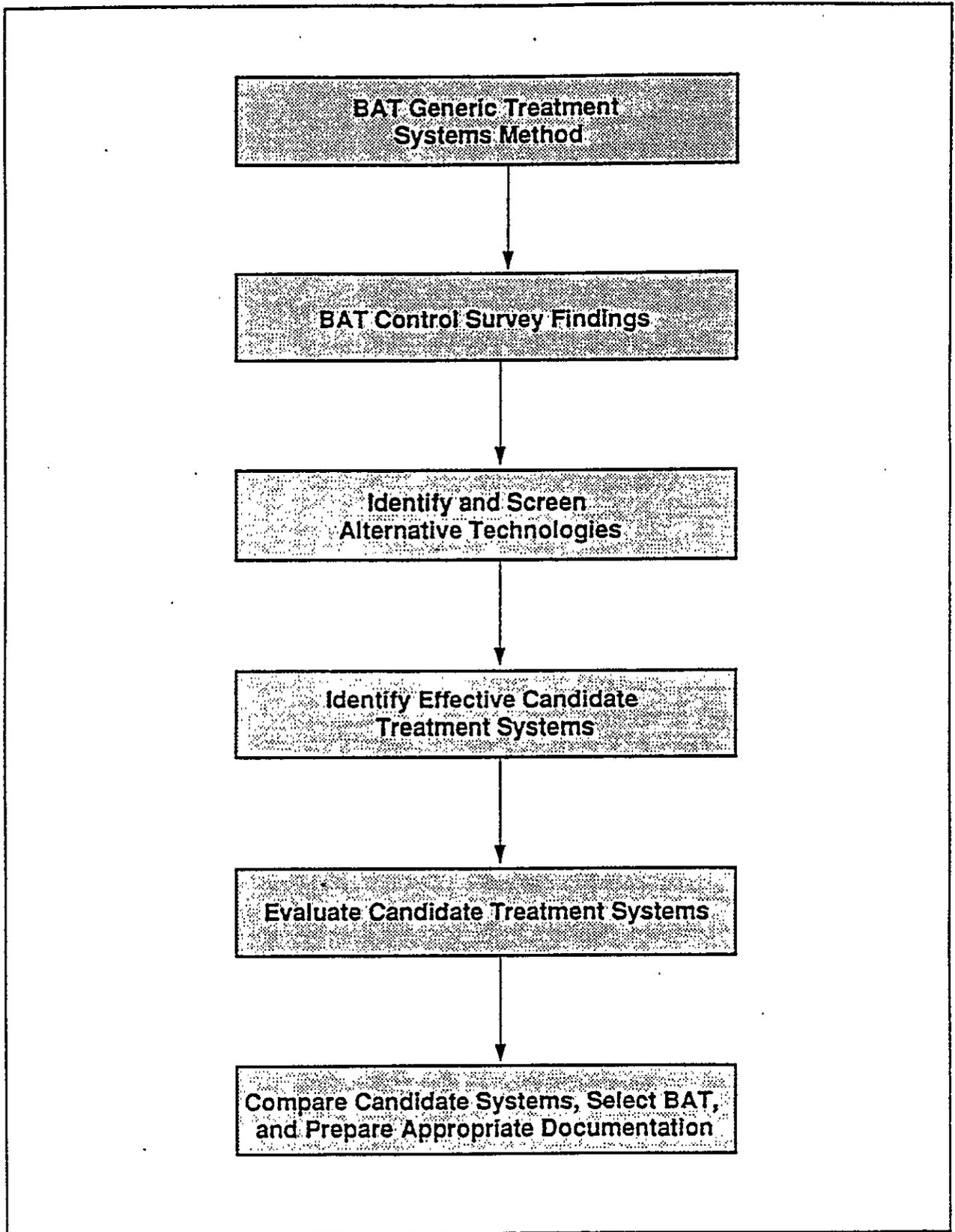


Figure 3-3. Procedure for selection of BAT using the Generic Treatment Systems Method.

Table 3-2. Toxic Weighting Factors

Constituent	WQC (ug/L)		WSDC		TWF
	Protection of Human Health	Protection of Freshwater Species (chronic)	uCi/L	ug/L	
<u>Organic Compounds</u>					
Halogenated Hydrocarbons (HH)					
Purgable Org. Halides (POX)					
Total Carbon					
Total Organic Carbon (TOC)					
Total Organic Halides (TOX)					
Acetone					
Bisethanoethanedithiol					
<b>Bis(ethylhexyl) phthalate</b>	1.50E+04	3.00E+00			1.87E+00
2-Butoxyethanol					
2-(2-butoxy ethoxy) ethanol					
Chlorodifluoromethane					
<b>Chloroform</b>	1.90E-01	1.24E+03			2.95E+01
Ethyl alcohol					
Methyl ethyl ketone					
Methylene chloride					
m-Xylene					
o-,p-Xylene					
2-Propanol					
<b>Tetrachloroethylene</b>	8.00E-01	8.40E+02			7.01E+00
<b>Toluene</b>	1.43E+04				3.92E-04
<b>1,1,1-Trichloroethane</b>	1.84E+04				3.04E-04
<b>Trichloroethene</b>	8.70E+01	2.19E+04			6.46E-02
Trichloromonofluoromethane					
Unknown					
Unknown aliphatic HC					
Unknown amide					
Unknown amine					
Unknown aromatic HC					
Unknown fatty acid					
Unknown fatty acid ester					
<b>Unknown PAH</b>	2.80E-03				2.00E+03

Table 3-2. Toxic Weighting Factors (cont.)

Constituent	WQC (ug/L)		WSDC		TWF
	Protection of Human Health	Protection of Freshwater Species (chronic)	uCi/L	ug/L	
<u>Inorganic Compounds</u>					
Aluminum					
Ammonia		2.10E+03			2.67E-03
Arsenic	2.20E-03	4.80E+01			2.55E+03
Barium	1.00E+03				5.60E-03
Beryllium	6.80E-03	5.30E+00			8.25E+02
Boron					
Bromide					
Cadmium	1.00E+01	1.10E+00			5.65E+00
Calcium					
Chloride					
Chromium	5.00E+01	2.10E+02			1.39E-01
Copper		1.20E+01			4.67E-01
Cyanide	2.00E+02	5.20E+00			1.10E+00
Fluoride					
Iron	3.00E+02	1.00E+03			2.43E-02
Lead	5.00E+01	3.20E+00			1.86E+00
Lithium					
Magnesium					
Manganese	5.00E+01				1.12E-01
Mercury	1.44E-01	1.20E-02			5.06E+02
Nickel	1.34E+01	1.60E+02			4.53E-01
Nitrate	1.00E+04				5.60E-04
Nitrite					
Phosphate					
Potassium					
Selenium	1.00E+01	3.50E+01			7.20E-01
Silicon					
Silver	5.00E+01	1.20E-01			4.68E+01
Sodium					
Strontium					
Sulfate					
Sulfide		2.00E+00			2.80E+00
Tin					
Titanium					
Uranium					
Vanadium					
Zinc		1.10E+02			5.09E-02

Table 3-2. Toxic Weighting Factors (cont.)

Constituent	WQC (ug/L)		WSDC		TWF
	Protection of Human Health	Protection of Freshwater Species (chronic)	uCi/L	ug/L	
<u>Radionuclides</u>					
Alpha activity			5.00E-05	8.16E-04	6.86E+03
Beta activity			3.00E-06	2.12E-08	2.64E+08
Am-241			4.00E-05	1.24E-05	4.53E+05
Co-60			5.00E-04	4.41E-07	1.27E+07
H-3 (tritium)			3.00E-02	3.10E-06	1.80E+06
Pu-239/240			5.00E-05	2.21E-04	2.53E+04
Radium total			3.00E-07	3.03E-07	1.85E+07
Ru-106			1.00E-04	2.98E-08	1.88E+08
Sr-90			3.00E-06	2.12E-08	2.64E+08
Uranium			3.00E-04	8.95E+02	6.26E-03
<u>Miscellaneous</u>					
Alkalinity					
Coliform					
Conductivity					
pH					
Suspended solids					
Temperature					
Total dissolved solids	2.50E+05				2.24E-05

NOTE: WQC = Water Quality Criteria  
WSDC = Washington State Deleterious Concentration  
TWF = Toxic Weighting Factor

The results of applying the generic treatment systems method are reported in subsequent sections of this report. The procedure began with a control survey to determine the necessary types of treatment in the context of project objectives as described in Section 4.1. The next step, as described in Sections 4.2 through 4.5, involved identification and screening of potential alternative treatment concepts and technologies. After the screening process was completed, five candidate treatment systems were identified. Each of the five candidates consisted of a combination of treatment alternatives remaining for consideration. Those candidate systems are presented in Section 4.6. Detailed evaluations of the candidate treatment systems are reported in Section 5. The process continued with a comparison of the candidates relative to each other. The comparison and selection processes are described in Section 6.

## 4.0 TREATMENT ALTERNATIVES

This section documents the screening procedure utilized in deriving five integrated treatment system alternatives. Each of the candidate systems has the potential for successfully treating the 300 Area Process Sewer wastewater and associated secondary wastes. The text discusses essential treatment system criteria, describes an array of potential treatment technologies, and explains how the BAT procedure was applied in reducing the matrix of technologies to five candidate treatment systems for further evaluation and comparison.

### 4.1 SCREENING OF WASTEWATER TREATMENT TECHNOLOGIES

During the initial screening effort, the Generic Treatment System Method incorporated in the BAT process as described in Section 3.1 identified a large array of alternatives for treating the subject wastewater. The technologies included source controls as well as pretreatment, treatment, and post-treatment processes with the potential for removing suspended solids, organics, and dissolved solids from the wastewater. In order to qualify for further consideration, these technologies, individually or in combination within an integrated system, were required to satisfy certain general criteria. For the wastewater treatment system addressed in this document, four essential criteria were established as follows:

- Mechanical and Technological Maturity  
Principal equipment items and fundamental technologies incorporated in the treatment system must be commercially demonstrated and readily available to meet the commitments of the Tri-Party Agreement. Specifically, the system must embody sufficient maturity to facilitate design, construction, and start-up within the timetable established by the Tri-Party Agreement.
- Effluent Water Quality  
The treatment system must provide reasonable assurance that acceptable, treated-effluent water quality will be achieved and maintained.
- Ambient Air Quality  
The treatment system must incorporate technology and operating procedures as necessary to prevent degradation of ambient air quality.
- Safety  
The process technology, equipment, and operating procedures utilized in the treatment system, individually and in combination, must provide superior levels of operator, public, and environmental safety.

Acceptable wastewater treatment technologies, individually or in combination within an integrated system, must also be able to effectively treat the various categories of contaminants expected in the wastewater. Within the context of this evaluation, there are two routes to effective treatment. The first route consists of physical, chemical, and thermal conversion of harmful substances into benign ones. The second route consists of capture and concentration of harmful substances supplemented with secondary waste treatment as

necessary to achieve the degree of stability required for safe disposal. The wastewater is expected to contain the following three types of contaminants:

- Suspended Solids
- Organics
- Dissolved Solids

Through application of the Generic Treatment System Method, a number of technologies having the potential for satisfactorily treating the three categories of contaminants were identified. Table 4-1 presents a matrix of those technologies along with several other alternatives including Source Control, No Action, and Zero Discharge. The table indicates which type of target contaminants each technology might be expected to substantially treat. Many of the technologies, however, are also somewhat effective in treating contaminant categories other than those shown.

For clarity, the technologies are listed individually in Table 4-1. However, most cases would require a combination of two or more compatible technologies to effectively treat the full range of contaminant categories in the wastewater. Each of the technologies in the matrix was evaluated within the context of the four essential project criteria defined above to reduce the list to only those suitable for the current application.

Sections 4.2 through 4.4 present generalized descriptions of the pretreatment and treatment technologies. The descriptions include rationales for retaining or eliminating those particular technologies from further consideration.

## 4.2 NO ACTION

The objective of WHC and DOE-RL is to reduce the quantity of harmful wastes contained in the subject wastewater to levels consistent with guidelines developed from relevant effluent water quality criteria. Examination of the wastewater characteristics indicate that pretreatment and treatment are necessary to achieve that objective. Treatment technologies have been identified and are available to implement the objective. Moreover, it is the stated intent of DOE to cease discharges of contaminated water to the soil column. Therefore, No Action is not an acceptable alternative within the BAT selection procedure.

## 4.3 SOURCE TREATMENTS

The following sections describe actions or alternatives available for reducing the volume of the wastewater or its constituent concentrations at the sources.

### 4.3.1 Source Control

In support of a Best Management Practices (BMP) approach, WHC has instituted a program of physical and administrative source controls and waste minimization of the 300 Area process sewer effluent (WHC 1990a and WHC 1990b). Implementation of the planned flow reduction and source control tasks will reduce the process sewer flow rate from 4920 lpm (1300 gpm) to about 757 lpm (200 gpm), reduce the concentration of some of the

Table 4-1. 300 Area Process Water Treatment Technologies

Treatment Technology	Target Contaminant Category		
	Suspended Solids	Organics	Dissolved Solids
<u>No Action</u>			
<u>Source Treatments</u>			
• Source Control	•	•	•
• Zero Discharge	•	•	•
<u>End-of-Pipe Treatments</u>			
• Off-site Disposal	•	•	•
• Suspended Solids Removal			
- Sedimentation/Clarification	•		
- Bag Filtration	•		
- Deep Bed Filtration	•		
- Cartridge Filtration	•		
- Microfiltration	•		
- Ultrafiltration	•		
• Organics Removal			
- Activated Carbon Adsorption		•	
- Biological Treatment		•	
- Supercritical Fluid Extraction		•	
- Air Stripping/Carbon Adsorption		•	
- UV/Ozone/Peroxide Wet Oxidation		•	
- Pervaporation		•	
• Dissolved Solids Removal			
- Coagulation/Flocculation			•
- Solar Evaporation	•		•
- Vacuum Freezing		•	•
- Chemical Precipitation			•
- Ion Exchange			•
- Ion Exchange/Electrolytic Regeneration			•
- Reverse Osmosis			•
- Electrodialysis			•
- Alumina Adsorption			•
- Algasorb			•
- Supported Liquid Membrane			•

constituents such as silver, and reduce the potential for chemical spills to the process sewer. These tasks include elimination of overflow from emergency water supply storage tanks, replacement of some HVAC water chillers with air-cooled units, drain plugging, various process modifications, the use of closed-loop cooling systems, and the implementation of additional administrative policy controls.

Additional source controls such as reduction or elimination of salt from regeneration of the Building 384 Powerhouse ion exchange columns are being reviewed.

Waste minimization and source controls are very appropriate for consideration in relation to the 300 Area process sewer. Source controls are being implemented and will be a significant portion of the selected BAT and, therefore, are retained.

#### 4.3.2 Zero Discharge

Achieving zero discharge would require either recycling the wastewater to other operations within the 300 Area or a complete shutdown of all operations which discharge to the process sewer. Each of those options poses substantial disadvantages.

The 300 Area Process Sewer wastewater is comprised of numerous small flows. Recycle would entail returning a portion of the wastewater back to its source for reuse. No major sources were identified which could accept raw wastewater for recycle. Additional options for recycle of the treated wastewater are being reviewed. Systems which would reuse the treated wastewater would have to be non-critical and would require backup water sources due to the variability inherent in the Process Sewer flow.

Laboratories, site-support facilities, and other miscellaneous facilities within the 300 Area discharge to the Process Sewer. Water discharged to the Process Sewer ranges from cooling water for experimental equipment, analytical instruments, and HVAC systems to overflow from emergency water storage tanks. Some of the facilities and programs which would be impacted by shut-down of the Process Sewer include the following:

- HWVP Feed Preparation Testing would require the installation of a closed loop cooling system resulting in a delay in testing and a subsequent one year delay in start-up of the HWVP.
- An alternative cooling water system for the A-Cell FRG canister storage rack would be required. Loss of cooling water would result in hot cell temperatures exceeding safe operating limits. Damage to the canisters would result in an eight million dollar loss.
- Alternative systems would have to be installed for water used to cool the hot gas thermoluminescent dosimeter readers located in the 318 complex. These readers are used to measure personnel dosimeters, environmental dosimeters, and nuclear accident dosimeters. Without alternate cooling systems, shut-down of the Process Sewer would result in the shut-down of virtually all work on the Hanford reservation, as personnel exposures could not be monitored.

- Closure of the Process Sewer would restrict or postpone operations within the 327 Building. Continued operation of this facility is very important to the success of current and projected FFTF and space power programs.

In addition to these major items, many other facilities would require extensive plumbing changes and procedure changes to collect and dispose the non-regulated effluents previously discharged to the Process Sewer. Therefore, zero discharge will not be considered further at this time.

#### **4.4 END-OF-PIPE TREATMENTS**

The following sections describe end-of-pipe treatment technologies identified during the screening process. These alternatives are grouped according to the type of contaminant they target for removal. The contaminant types include suspended solids, organics, and dissolved solids.

##### **4.4.1 Off-site Disposal**

Disposal of process sewer effluent off-site could entail discharging it to the city sewer system for treatment in the City of Richland Water Treatment Plant. A study commissioned by the city of Richland (Beck 1990) evaluated this option. Based on the results of this report it was determined that release of the process sewer effluent to the City of Richland Water Treatment Plant is not a viable option (Dronen 1991) and is eliminated from further consideration.

An alternate off-site disposal method would be to release the entire wastewater stream to an off-site vendor for appropriate disposal. The operation necessary to transport over 1,500,000 liters (400,000 gallons) of waste water off-site daily, potentially a distance of 1000 miles, is excessive and is eliminated from further consideration. Release of much smaller quantities of secondary waste to an off-site vendor, however, is more appropriate and will be considered further in Chapter 8.

##### **4.4.2 Suspended Solids Removal**

###### **4.4.2.1 Sedimentation/Clarification**

Sedimentation is the application of gravitational force to remove suspended particles from a fluid. The rate at which solids settle is affected by the size, shape, and density of the particle, and the density of the fluid. Types of clarification equipment include sedimentation basins and inclined-plate separators. Coagulants and flocculants are often added to the waste stream to increase the particle size and sedimentation rate. Following sedimentation, collected solids can be further dewatered using a drying bed, filtration, or centrifugation. Sedimentation typically requires little maintenance and is a standard method for removing suspended solids from waste water. It therefore, will be retained for further consideration.

#### 4.4.2.2 Bag Filtration

Bag filtration is commonly used to remove particles down to 1  $\mu\text{m}$ . The units consist of fabric bags supported by strainer baskets which are, in turn, housed within rigid casings. Fabric bags can degrade in the presence of certain organics, so materials must be selected carefully. The strainer basket and rigid housing must also be made of carefully selected materials. Bag filters are more prone to failure than are rigid cartridge filter media and require a high degree of contact maintenance. Therefore, this alternative was removed from further consideration.

#### 4.4.2.3 Deep Bed Filtration

Deep bed filters may contain one or more sizes of filter media such as sand and pulverized coal. The media are included in a layer or layers in a vertical cylinder through which wastewater flows in a downward direction. Particulates collect on the upper surface of the filter media. The collected solids are removed by back flushing. Usually two deep bed filters are provided to allow for continuous operation. One filter manufacturer has designed a continuously cleaned sand filter which avoids this batch operation required by back washing. Although the back-flush slurry requires settling or other methods to concentrate the solids, it is an attractive technology because very little maintenance involving human contact is required. Therefore, this technology will be carried forward for additional evaluation.

#### 4.4.2.4 Disposable Cartridge Filtration

Cartridge filters are used to remove particles ranging in size from submicron to 40  $\mu\text{m}$  from fluids containing 0.01% solids or less. Disposable cartridge filters can be constructed of a variety of materials including paper, cloth, and polypropylene. This type of filtration is typically operated in batch mode with the feed pumped through the cartridges until they are loaded with solids and the pressure differential exceeds operating specifications. The cartridges then are removed to be cleaned or disposed. The high level of contact-maintenance required for disposal of cartridge filters operated in batch mode preclude their use in the process sewer treatment plant. Therefore, the use of disposable cartridge filters is eliminated from further consideration.

#### 4.4.2.5 Microfiltration

Microfiltration is used to remove solid particles in the size range of 0.1 to 10  $\mu\text{m}$  (1,000 to 100,000Å). The technology uses elevated pressure to drive liquid waste through a membrane matrix containing extremely fine pores which trap particulates. The pH and organic content of the liquid stream must be compatible with the membrane material to prevent pluggage or physical damage. Membrane materials are typically polymeric but can also be ceramic or sintered metal.

Microfiltration is often a semi-continuous operation in which trapped particles are removed periodically by back-flushing of the filter membrane. Alternatively, microfilters can be used in recirculation/cross-flow operation: A recirculation loop is used which

includes a reservoir tank, a recirculation pump and the filter modules. The recirculation feature maintains a high velocity across the filter face to prolong on-stream time by avoiding solids accumulation at the surface. A small portion of the recirculation flow is bled off to maintain a constant solids concentration as feed water is added. Thus, extended filter life is obtained, but with higher pumping costs.

Due to the potential for automated, continuous cross-flow operation of ceramic or sintered metal filters this option will be evaluated further.

#### 4.4.2.6 Ultrafiltration

Ultrafiltration is similar to microfiltration except that it addresses particles in a size range from 0.001 to 0.1  $\mu\text{m}$  (10 to 1,000Å). There are similar design constraints on materials of construction. The membranes consist of a very thin skin supported on a spongy sublayer of membrane material. Like microfiltration, ultrafilters are usually operated in a recirculation cross-flow mode. The recirculation feature maintains velocity across the filter membranes to prolong on-stream time by avoiding solids accumulation at the membrane surfaces. Because of the relatively low demands expected to be placed on the filter for treating the process sewer effluent, this technology was eliminated from further consideration.

#### 4.4.3 Organics Removal

##### 4.4.3.1 Activated Carbon Adsorption

Commercially available activated carbon is widely used to adsorb organics contained in aqueous feed streams. Activated carbon is most effective when employed to adsorb relatively high-molecular-weight hydrocarbons that exhibit low solubility in aqueous solution. It is not as effective in adsorbing some organics such as small halogenated hydrocarbons. The adsorption process however is relatively non-selective and is commonly used as a broad-spectrum treatment method. There are two forms of activated carbon, granular (GAC) and powdered (PAC), which can be used.

GAC is typically used in flow-through columns, while PAC is used in well-mixed slurry reaction vessels. Some organics may exhibit a chromatographic effect after adsorption on GAC in which one adsorbed compound is displaced by another. Activated carbon adsorption was retained for further consideration due to its broad-spectrum applicability and standard use in wastewater and hazardous waste treatment.

##### 4.4.3.2 Biological Treatment

The use of biological processes is becoming more common in removing undesirable organics from wastewater streams. Sometimes, specific organisms are cultivated to target specific organic compounds. A given system often requires pH-adjustment, nutrient additions, and tight temperature control. The low carbon concentrations in the 300 Area process sewer effluent would also require that substantial carbon sources be added to sustain

a viable microbial population. Due to the wastewaters' low organic concentrations, biological treatment was eliminated from further consideration.

#### 4.4.3.3 Supercritical Fluid Extraction

Supercritical fluid extraction is an emerging technology for removing organics from wastewater using fluids which possess unique physical characteristics. The fluid (typically carbon dioxide) is obtained by compressing a gas to its critical point where it begins to behave as a liquid with the capacity for dissolving large quantities of organics. However, the fluid continues to exhibit some gaseous properties such as being able to extract organics at an extremely high rate compared with the rates normally observed for liquid-phase extraction. This technology is just emerging and cannot be considered as being commercially demonstrated for wastewater treatment. The high pressures required for this technology present additional concerns from a safety standpoint. Therefore, this alternative was eliminated from further consideration.

#### 4.4.3.4 Air Stripping/Carbon Adsorption

Air stripping may be used to remove low concentrations of volatile materials from wastewater. Air stripping towers are typically operated with counter-current flow of the air and water. The effectiveness of stripping is a function of the Henry's Law constant for a given constituent. A material with a Henry's Law constant of greater than 0.003 atm m<sup>3</sup>/mole is considered to be economically amenable to air stripping. The exhaust air may require further treatment prior to atmospheric discharge. The usual emission treatment is incineration or activated carbon adsorption. Given the low level of volatile organic constituents expected in the process sewer effluent, carbon adsorption would be more efficient than incineration. Several key nonvolatile organics, which air stripping would not effectively remove, have been identified in the process sewer effluent. Therefore, because other broad-spectrum treatment methods exist which do address all organics present, air stripping will not be considered further.

#### 4.4.3.5 Ultraviolet-Light/Ozone/Peroxide Oxidation

Ultraviolet (UV) oxidation is an organic destruction process which utilizes the tendency of hydrocarbons to absorb light within the UV spectrum. Having absorbed the light, the hydrocarbons are activated and become more susceptible to oxidation. The oxidant is typically provided in the form of ozone, hydrogen peroxide, or a mixture of the two. This process requires one-to-thirty minutes of residence time to effect near-complete oxidation. Residence time depends on contaminant type and concentration. Aromatic and other unsaturated hydrocarbons are more easily oxidized than are saturated organics. The equipment operates at room temperature and nominal pressure under continuous water flow conditions. UV/Ozone/Peroxide oxidation requires only monitoring of lamp activity/cleanliness and oxidant flows. Because it results in the destruction of most organics, the technology will be evaluated further.

#### 4.4.3.6 Pervaporation

Pervaporation is a membrane-based process which uses a vacuum to increase the membrane flux for organic wastewater constituents. The wastewater is directed across the upstream side of the membrane at ambient pressure and a slightly elevated temperature of 50°C to 90°C. The vapor-phase permeate is withdrawn by maintaining a slight vacuum on the downstream side of the membrane. Membranes are used which have a high selectivity for the organic compounds over water. Pervaporation cannot be considered as a demonstrated process at this time and is eliminated from consideration.

#### 4.4.4 Dissolved Solids Removal

##### 4.4.4.1 Coagulation/Flocculation

Coagulation and flocculation can be used to enhance the removal of metals and particulates from wastewater. Coagulating agents act to neutralize charges and collapse colloidal particles causing them to agglomerate or flocculate and settle. Common coagulants include aluminum sulfate (alum), ferric chloride, and ferric sulfate. In addition to these inorganic materials, polyelectrolytes can be used to flocculate colloidal particles. Polyelectrolytes are polymers of large, water-soluble organic molecules which react with, and bridge between, particles to form flocs.

The nature of the 300 Area process water makes it likely that some of the heavy metals are present as colloids, although the very low concentrations normally encountered indicate that part of the heavy metals are in solution. This process is a standard technique for removal of heavy metals from wastewater and will be retained for further analysis.

##### 4.4.4.2 Evaporation

Solar evaporation ponds would have to be double-lined and sized to accommodate the design wastewater flow rate. Based on the observed net evaporation rate of 94 centimeters (37 inches) of water per year at the Hanford Site and an average wastewater flow of 1135 lpm (300 gpm), a minimum of 170 acres of active pond area would be required. The pond would need to be 1.5 meters (5 feet) deep including 0.6 meters (2 feet) of freeboard. Providing a contingency pond to allow draining an active pond for leak repair would require, as a minimum, three ponds, each sized at 50% of the total capacity or about 85 acres each. As a result, the minimum total pond area would be about 255 acres. Construction of double-lined evaporation ponds of this size would cost approximately \$30,000,000 assuming a cost of \$3 per ft<sup>2</sup>. Given the disadvantages discussed above, solar evaporation is eliminated from further consideration.

Alternatively, evaporation of water can be enhanced by heating the wastewater. Evaporators of this type use elevated temperature and/or reduced pressure to evaporate water. Various methods can be used to provide the heat. Steam can be used directly or indirectly through heating coils. Mechanical vapor recompression (MVR) is another means for heating water. The key element of MVR is compression of the vapor resulting from the evaporation process. That compression raises the heat content and dewpoint of the vapor so

that it can be recycled as the evaporator heating medium. Essentially, the MVR step converts electrical energy supplied to the vapor compressor motor into thermal energy carried by the compressed vapor. The capital and O&M costs associated with evaporation of an 1135 lpm (300 gpm) waste stream are considered to be excessive. Use of an MVR evaporator however is retained for initial concentration of liquid secondary wastes.

#### 4.4.4.3 Vacuum-Freezing Multiple-Phase Transformation

Vacuum-freezing is a separation technique which utilizes freezing point differences and the unique properties of ice to remove dissolved solids from water.

Partial freezing of a wastewater produces a solid fraction consisting of pure ice. The remaining liquid contains the original impurities, but in a concentrated form. The ice crystals are removed and melted into relatively pure water (plus whatever brine adheres to the surface of the crystals after washing the ice) using the heat of condensation of the vapors produced in the initial vaporization step.

In a primary refrigerant mode, cold wastewater containing contaminants of low volatility is sprayed into a vacuum chamber at a pressure slightly below the vapor pressure of water at its freezing point so that simultaneous vaporization and freezing of the water occurs in an adiabatic (constant total heat content) mode. A sub-triple-point vapor and a slurry containing ice (water) crystals and a concentrated brine results. The low pressure flashes the feed water, and the heat of vaporization removed from the water causes ice crystals to form. About half the feed water is frozen.

The resulting mixture is transferred to the bottom of a separation column. There, the ice floats to the top, brine is drawn off the side of the separator at selected points. Vapor leaving the freezer is condensed in an auxiliary refrigeration system and is admitted to the top of the separation column to wash brine from the ice crystals.

Because of the complexity of this technology, and lack of demonstrated experience in concentrating similar waste streams, it was eliminated from further consideration as a primary treatment method. Though complex, this technology was retained for further consideration as a means of concentrating the secondary waste.

#### 4.4.4.4 Chemical Precipitation

Dissolved solids can be removed from solution by addition of a chemical agent which reduces the solubility of the target constituent causing a precipitate to form. Chemical precipitation is a common method for removal of toxic metals from wastewaters. Removal of dissolved metals usually involves adjusting the solution pH within a range of 8 - 11 to form insoluble hydroxides. Typical additives include sodium hydroxide, magnesium hydroxide, and hydrated lime. Many metals can also be precipitated using sodium sulfide or sodium bisulfide.

The precipitated solids are then removed typically by sedimentation and filtration. Various coagulants and flocculants are often added to assist in forming large, dense particles

which settle rapidly and are easily filterable. There are many variations of precipitation processes which can be used to target specific constituents.

One variation of the standard lime precipitation is a co-precipitation process. Co-precipitation can be accomplished by adjusting the solution pH to 2 to 4 to make a ferrous sulfate additive soluble. The ferrous sulfate is added and the mixture is agitated. The pH is readjusted via addition of hydrated lime ( $\text{Ca}(\text{OH})_2$ ) or sodium hydroxide. Iron precipitates as an oxyhydroxide ( $\text{FeOOH}$ ). Some contaminants are adsorbed on the  $\text{FeOOH}$ , some coprecipitate with the oxyhydroxide, and some precipitate as hydroxide. Microfiltration or clarification can be used to separate the resulting solids. There are also some proprietary coprecipitation processes such as Unocal's UNIPURE® process which may prove effective for this wastewater stream.

Chemical precipitation is a widely practiced and accepted process for removal of toxic metals from aqueous waste; therefore, it will be retained for further consideration.

#### 4.4.4.5 Ion Exchange

Ion exchange is a process in which ions are removed from an aqueous phase by displacement of complementary ions from exchange sites located on the surface of an insoluble support material. The support materials are typically synthetic organic resins. The complementary ions are composed of specific functional groups which are selectively displaced by ions in the solution. In cation resins, the exchange sites usually contain hydrogen ions but may also be designed and operated to contain sodium or ammonium ions. In anion resins, the exchange sites usually contain hydroxide ions, but other ions, such as chloride, can be used. Specialized ion exchange resins can also be effective in removing certain organic compounds.

A particular class of cation exchange resins which may be applicable to this waste stream are chelating resins. These organic resins have special functional groups attached which exhibit a high selectivity for many toxic metals. The slower kinetics of chelating resins require larger columns; however, the selectivity for heavy metals can result in a significant decrease in secondary waste in comparison to standard cation exchange resins.

Upon depletion of the available complementary ions, the resins are either removed for disposal and replaced with fresh resin or they are regenerated. Regeneration involves displacing contaminant ions with fresh, complementary ions to restore the exchange capacity of the resin. In conventional applications, cation or anion resins are typically regenerated by washing with sulfuric acid or sodium hydroxide solutions, respectively. Conventional regeneration usually generates secondary waste volumes up to 5% of the original flow rate.

Prerequisites for use of ion exchange include pretreatment for removal of suspended solids and organics. Both of those contaminants can mask the exchange sites, resulting in loss of exchange efficiency, and plug the resin bed, resulting in restricted flow through the unit. Despite the substantial secondary waste volume and the requirement for pretreatment, ion exchange is a standard water treatment technology and has the potential for effective

removal of dissolved solids from the wastewater. Therefore, the technology was retained for further evaluation.

#### 4.4.4.6 Ion Exchange and Electrolytic Regeneration

One emerging ion exchange technology offers the potential for reduced secondary waste volumes and reduced operating costs when compared with conventional ion exchange. This alternative, developed by Millipore, is trade-named Ionpure® and uses an electrolytic process to continuously regenerate a mixed bed of anionic and cationic resins. In Ionpure® units, the resins are sandwiched between alternating layers of anion- or cation-permeable membranes. An electric current regenerates the resin, eliminating the use of any supplemental chemicals. Although Ionpure® is an attractive process, neither the specialized membranes nor the electrolytic regeneration is considered commercially demonstrated for removing the constituent ions of interest in the process sewer effluent. Therefore, the technology was eliminated from further consideration.

#### 4.4.4.7 Reverse Osmosis

Reverse osmosis (RO) is a physical unit process which removes dissolved molecules, anions, and cations from an aqueous solution and concentrates them. The process involves filtering the contaminated solution through a semi-permeable membrane at a pressure greater than the osmotic pressure exerted by the dissolved constituents in the wastewater. Relatively pure water passes through the membrane while most of the impurities do not.

An RO unit produces two streams from the original feed stream. The first is permeate which consists of relatively pure water. The second is concentrate which consists of water-carrying impurities which did not pass through the membrane. To achieve enhanced concentration of the removed contaminants, applications frequently employ two or more RO stages operating in series. In such applications, the permeate streams are combined for discharge while the feed stream to each of the latter stages consists of concentrate produced in the previous stage. In a given RO stage, the fraction of the total feed water appearing in the permeate stream is primarily a function of the operating pressure upstream of the membrane which, in turn, is established by the design criteria for the desired level of contaminant removal.

For effective removal of dissolved solids from the 300 Area process sewer wastewater, several stages of reverse osmosis would be applied in series. Colloidal and organic matter tend to foul RO membrane surfaces, causing significant deterioration in the rate of water throughput. Therefore, its application would require pretreatment steps, including filtration and TOC removal. Secondary waste volumes typically range from 10% to 20% of the original flow rate. Even with the prerequisites for pretreatment and large volumes of secondary waste, RO appears to be a viable alternative for removing contaminants from the wastewater and was retained for further evaluation.

#### 4.4.4.8 Electrodialysis

Ion exchange membranes in a direct-current electrical field are used in electrodialysis to separate ionic species in a fluid. In comparison to reverse osmosis, electrodialysis can result in retentate or reject streams which are significantly more concentrated. However leakage to the permeate is greater with electrodialysis, resulting in a "dirtier" product stream. Electrodialysis, therefore, will not be evaluated further for treatment of the process sewer effluent.

#### 4.4.4.9 Alumina Adsorption

Activated alumina is used to adsorb ions from the wastewater as it passes through a packed column. The alumina can be regenerated by rinsing with basic and acidic solutions such as sodium hydroxide and nitric acid, respectively. Anions of arsenic are often adsorbed using activated alumina. Activated alumina was not considered further because there are other broader-spectrum separation methods available for treating this wastewater.

#### 4.4.4.10 Algasorb

Algasorb is a registered name for a dried algae which has been formed into beads for use as a chemical sorbent. Sorbed species are removed by adjusting the solution pH. This medium has been shown to be quite effective for sorbing certain heavy metals, including uranium. Its applications involve concentrating weak solutions of specific metal ions to facilitate further processing of the solution. Careful control of pH during sorption is required. Algasorb was eliminated from further consideration because its treatment functions are achieved by other, more-proven technologies.

#### 4.4.4.11 Supported Liquid Membrane

Supported liquid membrane (SLM) is an emerging technology with the potential for removing and concentrating dilute contaminants from an aqueous feed stream. An SLM consists of an organic extractant held by capillary forces within the pores of a microporous membrane. The feed solution is flushed across one side of the membrane. The organic solvent extracts solute from the feed. Concurrently a stripping solution is flushed across the other side of the membrane to remove the solute from the organic solvent.

Applied to the 300 Area process sewer waste stream, an SLM unit would be configured with multiple types of membranes in series to effectively remove both cations and anions. The process would be expected to generate a relatively small volume of secondary waste comprised of a flushing solution carrying the removed impurities. Filtration and TOC removal are necessary pretreatment steps to avoid plugging or blinding the membranes. The technology cannot be considered commercially demonstrated at this time. Therefore, it was eliminated from further consideration.

## 4.5 SCREENING SUMMARY

Table 4-2 presents a summary of the decisions discussed above regarding whether each alternative treatment technology was to be retained for further evaluation or eliminated from consideration.

## 4.6 CANDIDATE TREATMENT SYSTEMS

The remaining technologies were combined into five candidate treatment systems for further evaluation and comparison. Each of the candidate systems addresses the three contaminant categories and satisfies the four essential project criteria. Table 4-3 presents a summary of the alternatives in terms of which contaminant categories are addressed by each technology.

The first alternative provides a single stage of removal for each of the three target contaminants, while the second and third add a second stage of removal for dissolved solids. The fourth and fifth alternatives provide two stages of suspended solids removal and a second, standby stage of dissolved solids removal. The alternatives were developed such that all retained treatment technologies are considered.

The five candidates are presented in this section. Their presentation consists of diagramming the process train and briefly describing how the system removes compounds of concern. In the next chapter of this report, the candidates will be examined in more detail. This examination includes discussion on methods of treating secondary wastes generated by each candidate to prepare the wastes for storage and/or disposal.

It should be noted that all of these treatment alternatives utilize source controls as a key component. Additionally, for all alternatives, two, 3.8 million liter (1-million gallon) diversion basins will be used to hold all process water which contains hazardous materials in concentrations above the design capacity of the treatment system. Such material would be treated by mixing it in the appropriate ratio with normal effluent once standard conditions are restored. The basins would also serve as surge capacity during periods of maintenance requiring extended shutdown of the process.

### 4.6.1 Alternative 1

Alternative 1 is comprised of three treatment unit operations: filtration, granular activated carbon (GAC) adsorption, and ion exchange (IX). The process is sketched in Figure 4-1 which includes ancillary equipment and equipment to treat secondary waste streams.

Each of the major treatment components removes contaminants of concern. Filtration will be used to remove suspended solids. The GAC adsorption removes the majority of organic compounds. IX removes most of the dissolved ions from the wastewater, capturing them on resin beads. Secondary wastes produced by this process include filtered solids, spent carbon, and exhausted IX resin or used IX regenerating solution. The carbon will require regeneration and the IX resin or regenerating solution may require further treatment

Table 4-2. Results of Screening 300 Area Process Water Treatment Technologies

Treatment Technology	Initial Screening Result	
	Eliminated	Retained
<u>No Action</u>	•	
<u>Source Treatments</u>		
• Source Control		•
• Zero Discharge	•	
<u>End-of-Pipe Treatments</u>		
• Off-site Disposal	•	
• Suspended Solids Removal		
- Sedimentation/Clarification		•
- Bag Filtration	•	
- Deep Bed Filtration		•
- Cartridge Filtration	•	
- Microfiltration		•
- Ultrafiltration	•	
• Organics Removal		
- Activated Carbon Adsorption		•
- Biological Treatment	•	
- Supercritical Fluid Extraction	•	
- Air Stripping/Carbon Adsorption	•	
- UV/Ozone/Peroxide Wet Oxidation		•
- Pervaporation	•	
• Dissolved Solids Removal		
- Coagulation/Flocculation		•
- Solar Evaporation	•	
- Vacuum Freezing	•	
- Chemical Precipitation		•
- Ion Exchange		•
- Ion Exchange/Electrolytic Regeneration	•	
- Reverse Osmosis		•
- Electrodialysis	•	
- Alumina Adsorption	•	
- Algasorb	•	
- Supported Liquid Membrane	•	

Table 4-3. Candidate Waste Treatment Systems

Candidate Number	Treatment/Pretreatment Processes	Target Contaminants
1	Source Control Filtration Granular Activated Carbon Ion Exchange	All Suspended Solids Organics Dissolved Solids
2	Source Control Filtration Granular Activated Carbon Reverse Osmosis Ion Exchange	All Suspended Solids Organics Dissolved Solids Dissolved Solids
3	Source Control Filtration UV Oxidation Reverse Osmosis Ion Exchange	All Suspended Solids Organics Dissolved Solids Dissolved Solids
4	Source Control Chemical Precipitation Clarification Filtration Granular Activated Carbon Ion Exchange (standby)	All Dissolved Solids Suspended Solids Suspended Solids Organics Dissolved Solids
5	Source Control Coagulation/Flocculation Powdered Activated Carbon Clarification Filtration Ion Exchange (standby)	All Dissolved Solids Organics Suspended Solids Suspended Solids Dissolved Solids

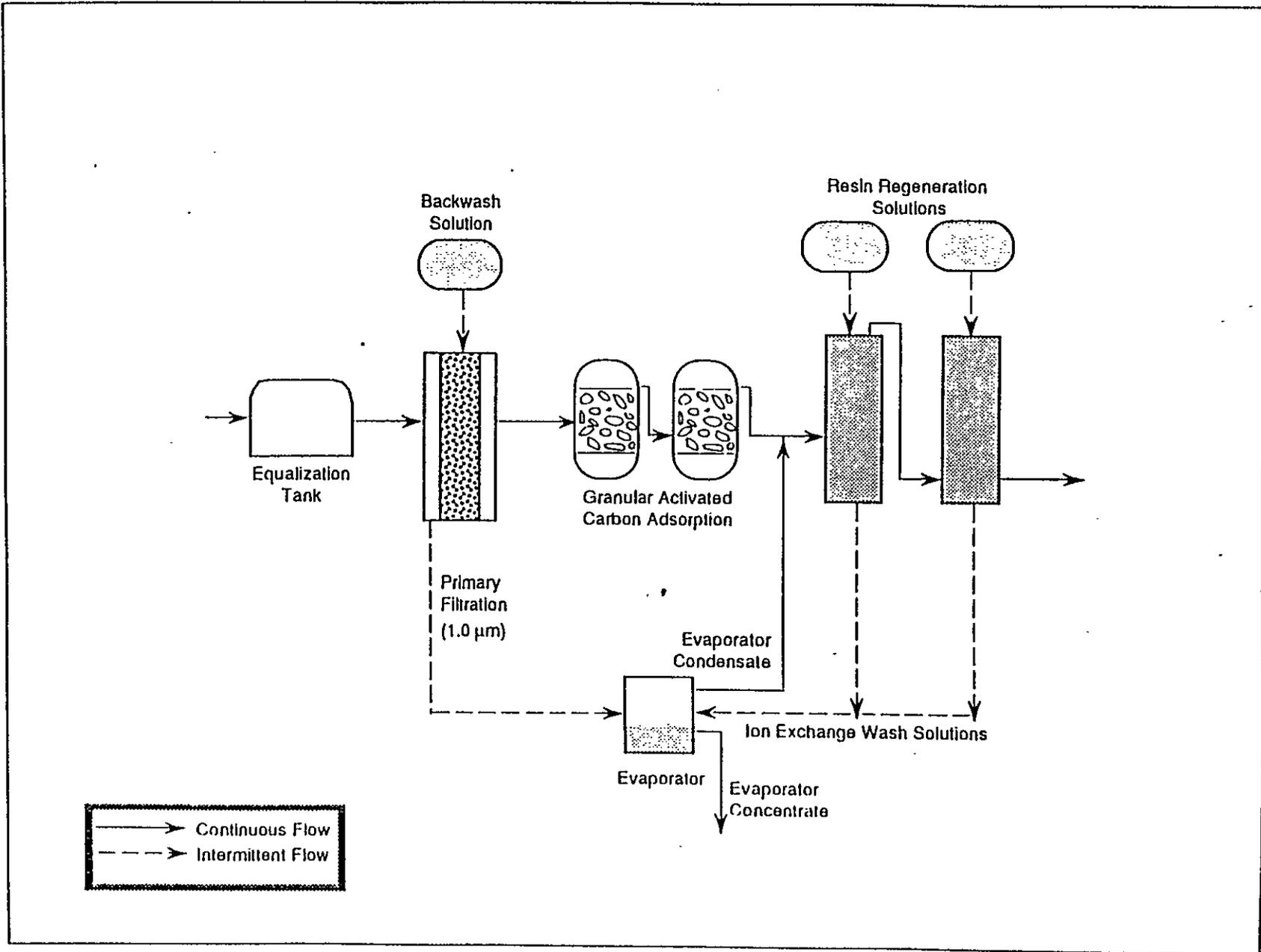


Figure 4-1. Diagram of Alternative 1 process train.

prior to storage or final disposal.

#### 4.6.2 Alternative 2

Alternative 2 consists of filtration, GAC adsorption, reverse osmosis (RO), and IX. The candidate process is illustrated in Figure 4-2. Alternative 2 is very similar to Alternative 1 except that RO is added as a precursor to ion exchange for dissolved solids removal. Otherwise, the system operates as described in Section 4.2.1. The retentate from the RO unit will require further treatment prior to final disposal.

#### 4.6.3 Alternative 3

Alternative 3 consists of filtration, UV/ozone/peroxide oxidation, RO, and IX. The process is diagrammed in Figure 4-3. Alternative 3 is very similar to Alternative 2 except that UV/oxidation replaces GAC adsorption as a treatment step for removal of organic compounds. The effect of this addition, to be discussed in more detail later, is the destruction of the organics rather than the capture of the organic compounds on activated carbon. Otherwise, the system operates as described in Section 4.2.2.

#### 4.6.4 Alternative 4

The Alternative 4 process train consists of chemical precipitation, clarification, filtration, GAC, and standby IX. Alternative 4 is diagrammed in Figure 4-4.

In this alternative, no pretreatment is required. The majority of the toxic metals are removed by coprecipitation. The precipitated solids are then settled in a clarifier. After settling, the clarified supernatant passes through a deep bed filter. GAC is then used to remove the organic constituents. A two-stage or mixed-bed ion exchange system is kept in standby. This system provides a second level of dissolved solids removal for use during process upsets. The IX will typically be used for treating water that has been diverted to the basins. The settled solids are dewatered prior to disposal. The quantities of IX resin exhausted are anticipated to be too small to economically regenerate.

#### 4.6.5 Alternative 5

Coagulation/flocculation, powdered activated carbon (PAC) adsorption, clarification, filtration, and standby IX are the Alternative 5 unit operations. Figure 4-5 is a diagram of the Alternative 5 process train. This alternative is similar to Alternative 4 except that coagulation rather than coprecipitation is used for metals removal. Powdered activated carbon (PAC) is also added during the coagulation step. The PAC adsorbs organics and is removed in the clarifier along with the coagulated solids.

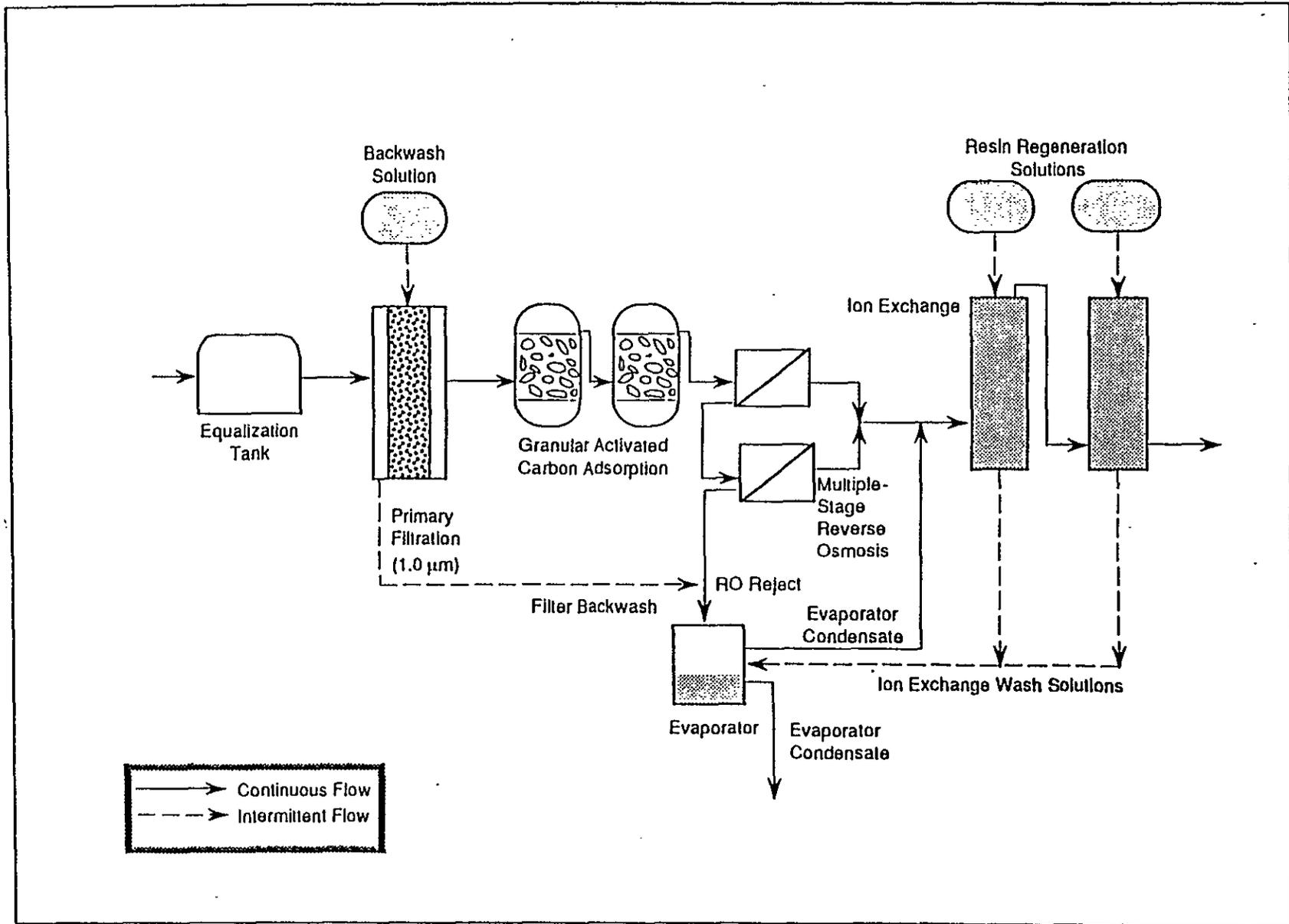


Figure 4-2. Diagram of Alternative 2 process train.

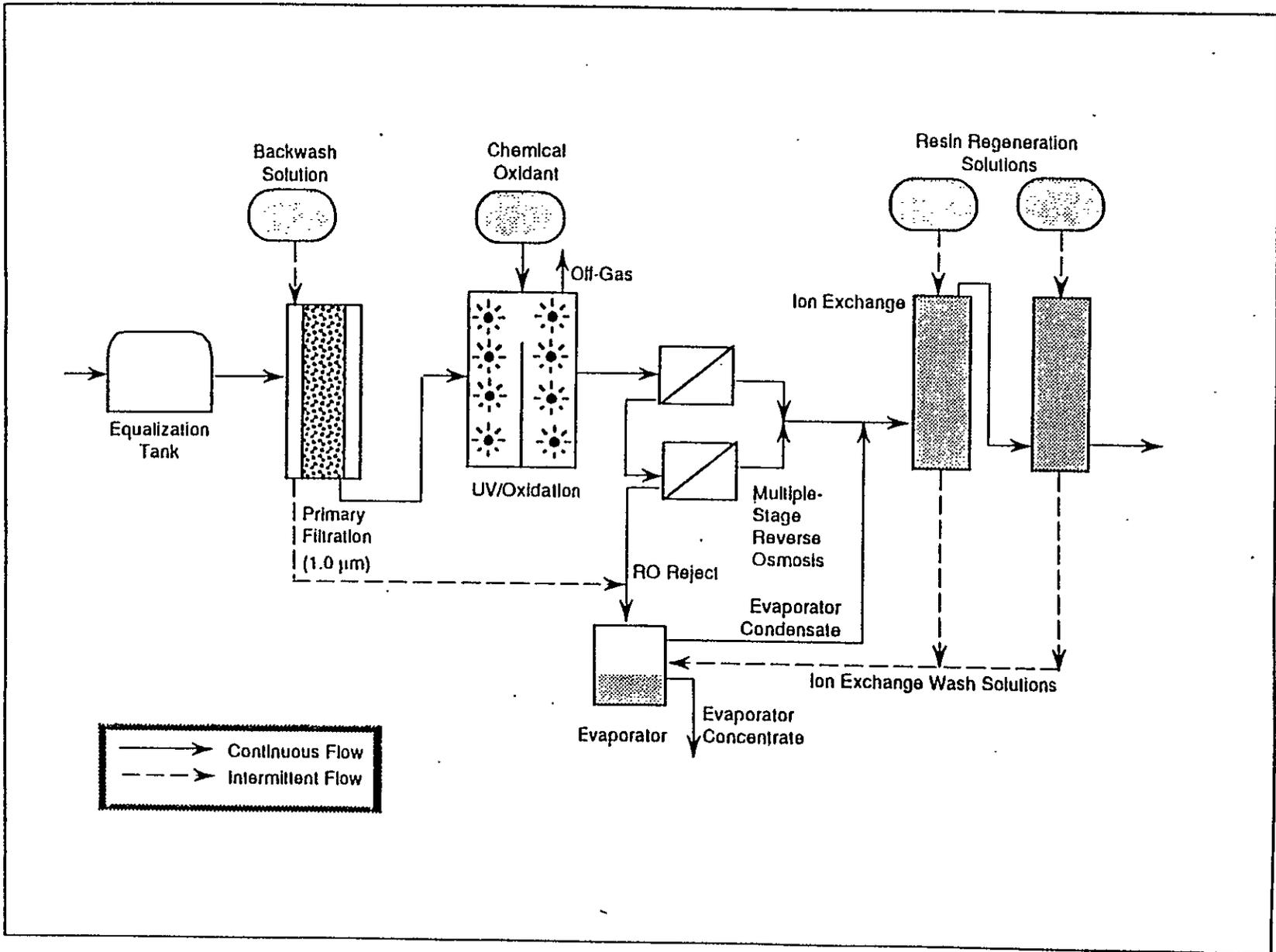


Figure 4-3. Diagram of Alternative 3 process train.

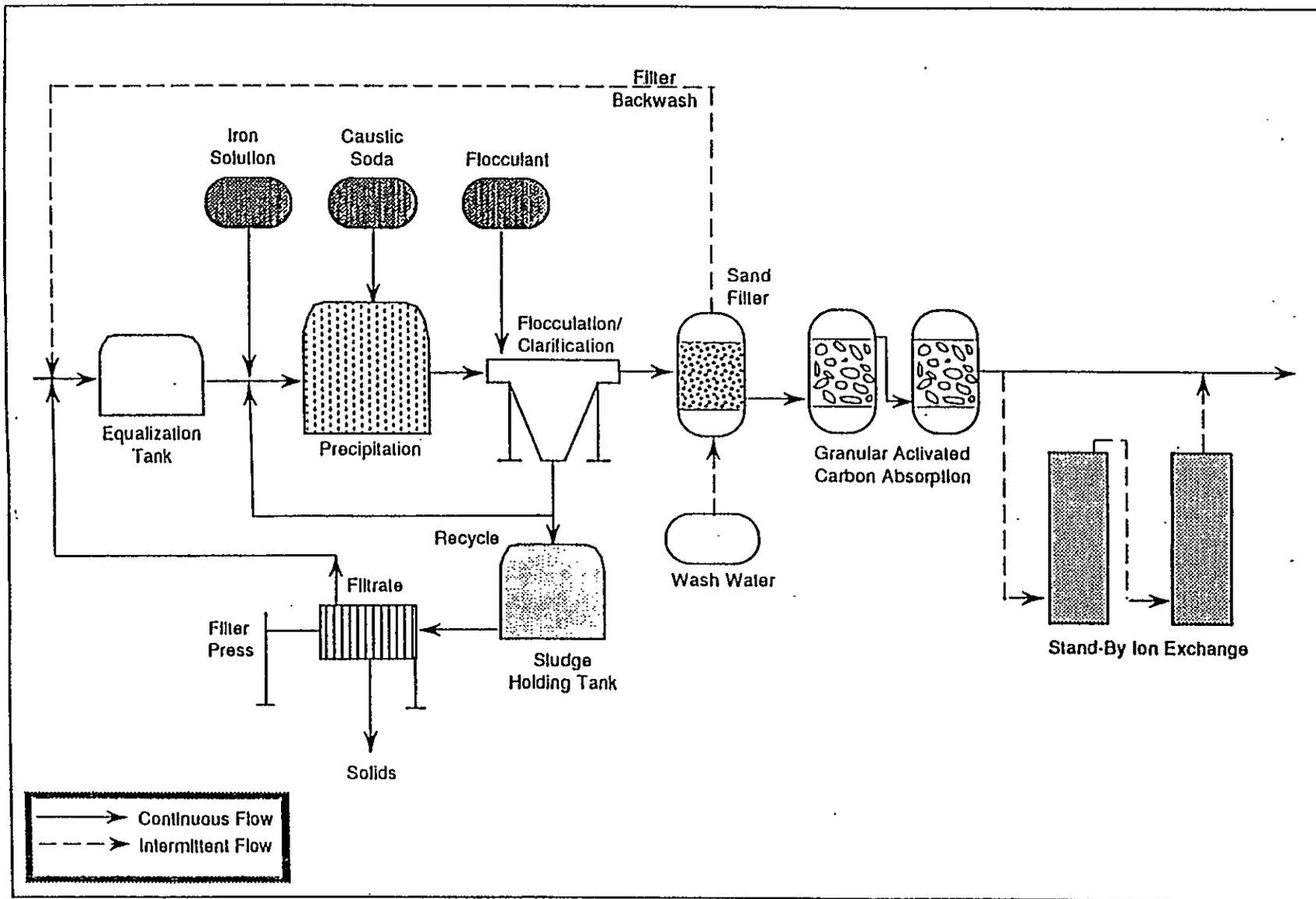


Figure 4-4. Diagram of Alternative 4 process train.

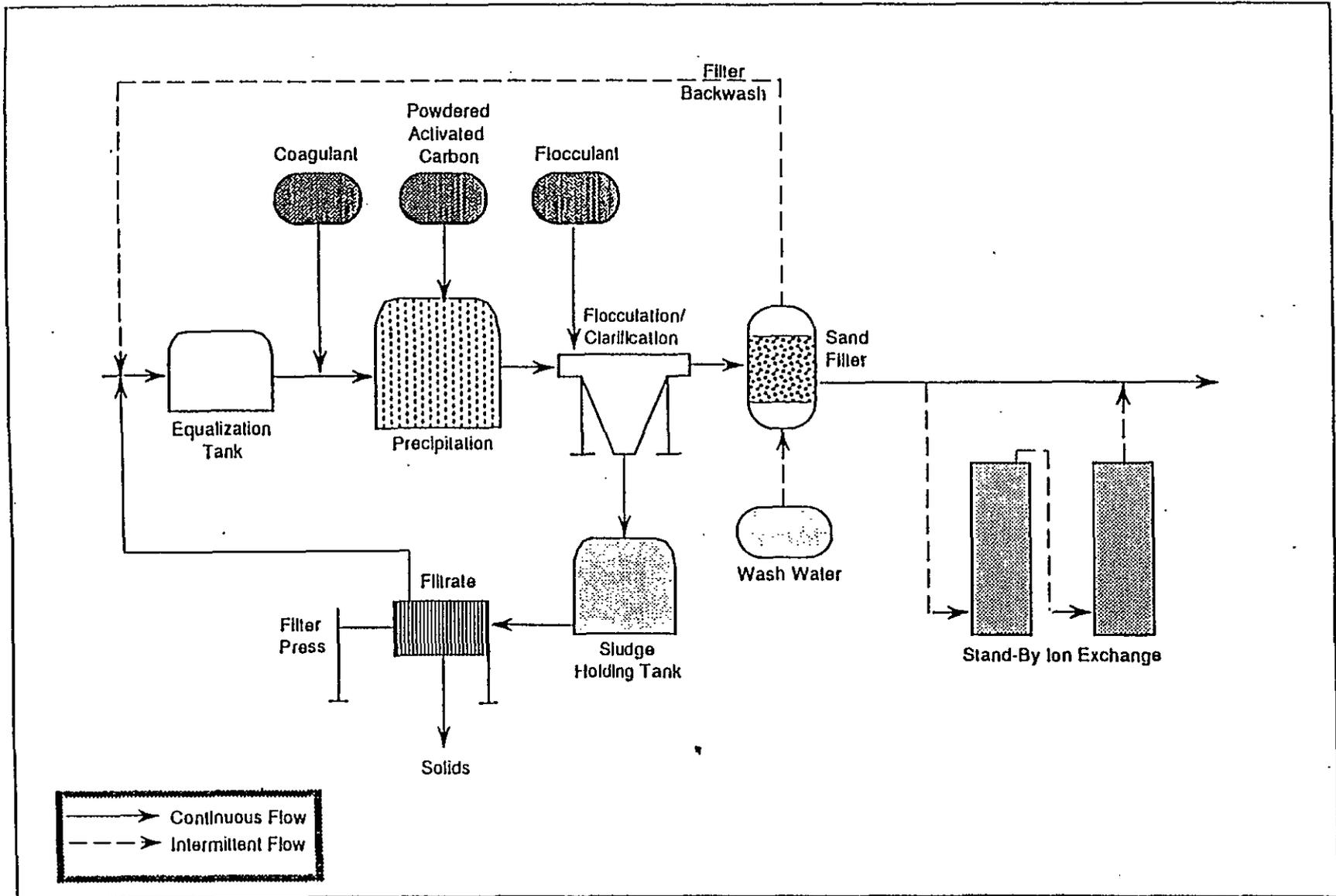


Figure 4-5. Diagram of Alternative 5 process train.

## 5.0 DESCRIPTION OF CANDIDATE TREATMENT SYSTEMS

The five candidate treatment systems are described in detail in this chapter. Five parallel sections describe the processes and eight elements of each alternative. These elements, as shown below, will later serve as the basis for comparing alternatives and selecting one as the preferred option:

- Treated Water Quality
- Secondary Wastes
- Flexibility
- Reliability
- Safety
- Technical Viability
- Capital and Operating Costs
- Ease of Maintenance

Because of the similarity of several of the process alternatives, the discussion of alternatives is limited to differences between the alternatives. The alternatives are evaluated and compared in Chapter 6.

### 5.1 ALTERNATIVE 1

#### 5.1.1 Process Description

Alternative 1 consists of filtration, granular activated carbon (GAC) adsorption, and ion exchange. Ancillary unit operations include a holding tank preceding the filter, intermediate holding tanks, and a system for concentrating secondary waste streams. The process diagram was shown previously (see Figure 4-1). All these components are described in detail in the following text.

A holding tank precedes the treatment system. One purpose of this tank is to provide operating flexibility. For example, the tank may continue to fill while the treatment process is shut down for servicing. The tank also equalizes the flow of the entering waste stream, providing a more consistent composition and flow rate to the treatment equipment. The tank volume is about 190,000 liters (50,000 gallons) and is constructed of corrosion-resistant materials.

A filter is the first treatment component. The purpose of this component is to remove particles 1 micron and larger. In addition to removing the particles, the filter may also remove some of the heavy metals that are adsorbed to the particles. There are two viable options for filters in this application. One option is a tubular filter element with 1 micron pores, constructed of sintered ceramic or metal particles. These filters capture solids on their exterior while allowing water and dissolved matter to pass through. This type of filter can be backwashed in place to avoid constantly producing waste filters typical of conventional cartridge filtration. The second option is a mixed-media "sand" filter, which captures particles in the pores created by the sand. A variation of the sand filter is the use of silica sand coated with oxidized iron. The oxidized iron adsorbs dissolved heavy metals. Thus, particle-bound metals and dissolved metals are removed with this type of filter. Two of the selected type of filter are included in Alternative 1, one on-line and the second as a stand-by.

The filter is backwashed regularly to remove solids that collect on the filter elements or within the sand filter. The backwashing will be automatic, based on measured pressure drops across the filter. Thus, the backwashing frequency will depend on the suspended solids loading and particle size distribution of the 300 Areas wastewater.

Filtrate is next pumped through vessels of GAC for removal of organic compounds. Two vessels are used in series. For the design flow of 1135 lpm (300 gpm), vessels 3 meters (10 feet) in diameter and 3 meters (10 feet) high packed with 9000 kg (20,000 lbs) of GAC each are adequate. This size provides a contact time of just over 15 minutes per vessel. Monitoring of water quality is performed at the discharge from each vessel to detect "breakthrough" of the target compounds. When breakthrough occurs in the first vessel, the GAC is removed hydraulically and replaced with fresh GAC. The flow through the two vessels is then switched to direct water through the second vessel first and the vessel with the fresh GAC second. This alternation is continued throughout the operation. The spent GAC is dewatered, tested for chemical constituents, then sent to a permitted facility for regeneration.

Ion exchange is the final treatment step. Two ion exchange columns are used in series, one with cation and one with anion exchange resin. There are two such series of separated resin columns operating in parallel, and a third on standby. Each ion exchange column is 1.2 meters (4 feet) in diameter, 3.7 meters (12 feet) high, and holds 4.27 cubic meters (151 cf) of ion exchange resin. Conductivity is used to measure breakthrough of an operating column. When the column is spent, a standby column is brought into service. The spent column is drained of water and then is regenerated. The regeneration process begins by first backwashing the resin column to remove particles captured in the bed. Then, sulfuric or hydrochloric acid is used to regenerate the cation exchange resin. Sodium hydroxide is used to regenerate the saturated anion exchange resin. After regeneration, the ion exchange column is flushed with clean water. Then the column is placed in stand-by until another column is due for regeneration.

The treated water is discharged continuously in this alternative. On-line sampling is conducted to verify the quality of the effluent water.

A mechanical vapor recompression (MVR) evaporator is used to concentrate the backwash water from the filter system and the regeneration water from the ion exchange system. The purpose of the evaporator is to reduce the volume of secondary waste produced by this alternative by removing some of the water. The MVR evaporator is a thermally efficient design in which a compressor is used to compress the evaporated vapor and pass it through a heat exchanger in order to transfer energy to the incoming water. The use of the compressor results in a high thermal efficiency and nearly eliminates the need for any energy input other than the compressor power. The material concentrated in the evaporator will have a total solids concentration of approximately 20%. The evaporated water will be condensed and returned to the treatment system. It is assumed that the condensed water will require ion exchange to remove residual contaminants. Further design may determine that this is unnecessary. If ion exchange is used, the evaporator condensate must be cooled to 25 °C or less prior to treatment.

### 5.1.2 Treated Water Quality

The predicted effluent water quality is tabulated in Table 5-1. The first column of numbers shows the untreated water quality. The second column shows concentrations of the specific compounds after treatment by the entire process train. The third column indicates the overall decontamination factor (DF) for the process train. The fourth column lists the total estimated quantity of the particular compounds that are removed annually. The final column tabulates the toxic mass removed.

There are a number of generalizations that can be made regarding the treatment effectiveness of the process. Many organic compounds are reduced to less than 5 percent of their original concentration through the use of GAC adsorption. The overall removal of total organic carbon (TOC) is about 95 percent. Heavy metal ions and other inorganic compounds are removed by filtration and ion exchange to levels less than an estimated 0.7 percent of their influent concentrations. Treatability testing will be conducted to identify the decontamination factors that will actually be available in the full-scale facility.

The decontamination factors (DFs) listed in Table 5-1 and similar tables for the other alternatives are a combination of the individual DFs for the unit operations. The unit operation DF values were obtained from multiple sources. A primary source was a database compiled by the EPA listing the actual performance of technologies in treating particular compounds (EPA 1990). Vendor estimates of DFs were used for a number of compounds. In cases where DF values were not available for compounds of interest, estimates were based on similar chemicals for which DF values were available. For example, a DF for removal of certain divalent metals by RO was found to be about 100, so most divalent metal ions were assumed to have similar values.

### 5.1.3 Secondary Wastes

All of the unit operations comprising Alternative 1 produce secondary waste, either directly or indirectly. Specifically, the filtration systems produce backflush water, which is then concentrated in an MVR evaporator which accompanies the process; the GAC adsorption system produces spent activated carbon; and the ion exchange system produces

Table 5-1. Alternative 1: Treated Water Quality

Constituent	Design Influent Concentrations	Final Effluent Concentrations	Total Decontamination Factor	Total Mass Removed By System	Toxic Mass Removed by System
<u>Organic Compounds</u>	(ppb)	(ppb)		(kg/yr)	(kg/yr)
Acetone	70	4	20	3.96E+01	
Bis(ethanolthanedithiol	1	0.05	20	5.68E-01	
Bis(ethylhexyl)phthalate	80	1	100	4.72E+01	8.83E+01
2-Butoxyethanol	1	0.05	20	5.66E-01	
2-(2-butoxy ethoxy) ethanol	100	5	20	5.66E+01	
Chlorodifluoromethane	20	1	20	1.13E+01	
Chloroform	40	2	20	2.26E+01	6.68E+02
1,1-Dichloroethane	40	0.40	100	2.36E+01	
Dichlorodifluoromethane	3	0.15	20	1.70E+00	
Ethyl alcohol	3	0.15	20	1.70E+00	
Halogenated hydrocarbons	9	0.45	20	5.10E+00	
Methyl ethyl ketone	5	0.25	20	2.83E+00	
Methylene chloride	4	0.08	50	2.34E+00	
m-Xylene	1	0.01	100	5.90E-01	
o-p-Xylene	1	0.01	100	5.90E-01	
Purgable Organic Halides (POX)	6	0.06	100	3.54E+00	
2-Propanol	4	0.04	100	2.36E+00	
Tetrachloroethylene	10	0.10	100	5.90E+00	4.14E+01
Total Organic Carbon (TOC)	6,000	300	20	3.40E+03	
Toluene	2	0.02	100	1.18E+00	4.63E-04
Total Carbon	14,000	700	20	7.93E+03	
Total Organic Halides (TOX)	200	10	20	1.13E+02	
1,1,1-Trichloroethane	10	0.1	100	5.90E+00	1.79E-03
Trichloroethene	0.4	0.004	100	2.36E-01	1.52E-02
Trichloromonofluoromethane	1	0.05	20	5.66E-01	
Unknown	50	50	1	0.00E+00	
Unknown aliphatic HC	3	0.3	10	1.61E+00	
Unknown amide	2	0.2	10	1.07E+00	
Unknown amine	10	1.0	10	5.36E+00	
Unknown aromatic HC	4	0.4	10	2.15E+00	
Unknown fatty acid	30	3	10	1.61E+01	
Unknown fatty acid ester	1	0.1	10	5.36E-01	
Unknown PAH	40	4	10	2.15E+01	4.29E+04
<u>Inorganic Compounds</u>	(ppb)	(ppb)		(kg/yr)	(kg/yr)
Aluminum	350	0.350	1000	2.08E+02	
Ammonia	400	0.200	2000	2.38E+02	6.36E-01
Arsenic	10	0.050	200	5.93E+00	1.51E+04
Barium	60	0.120	500	3.57E+01	2.00E-01
Beryllium	30	0.075	400	1.78E+01	1.47E+04
Boron	25	0.050	500	1.49E+01	
Bromide	4	0.040	100	2.36E+00	
Cadmium	10	0.010	1000	5.95E+00	3.36E+01
Calcium	30,000	150	200	1.78E+04	
Chloride	60,000	600	100	3.54E+04	
Chromium	10	0.01	1000	5.95E+00	8.28E-01
Copper	80	0.08	1000	4.76E+01	2.22E+01

Table 5-1. Alternative 1: Treated Water Quality (cont.)

Constituent	Design Influent Concentrations	Final Effluent Concentrations	Total Decontamination Factor	Total Mass Removed By System	Toxic Mass Removed by System
	(ppb)	(ppb)		(kg/yr)	(kg/yr)
Cyanide	50	0.5	100	2.95E+01	3.25E+01
Fluoride	200	2	100	1.18E+02	
Iron	600	0.6	1000	3.57E+02	8.68E+00
Lead	60	0.06	1000	3.57E+01	6.65E+01
Lithium	30	0.30	100	1.77E+01	
Magnesium	5,000	25	200	2.97E+03	
Manganese	60	0.06	1000	3.57E+01	4.00E+00
Mercury	3	0.003	1000	1.79E+00	9.04E+02
Nickel	60	0.06	1000	3.57E+01	1.70E+01
Nitrate	6,000	60	100	3.54E+03	1.98E+00
Nitrite	400	4	100	2.36E+02	
Phosphate	1,000	5	200	5.93E+02	
Potassium	1,000	10	100	5.90E+02	
Selenium	6	0.006	1000	3.57E+00	2.57E+00
Silicon	3,000	6	500	1.78E+03	
Silver	20	0.02	1000	1.19E+01	5.69E+02
Sodium	40,000	400	100	2.36E+04	
Strontium	100	0.1	1000	5.95E+01	
Sulfate	30,000	60	500	1.78E+04	
Sulfide	100	0.2	500	5.95E+01	1.67E+02
Tin	100	0.1	1000	5.95E+01	
Titanium	7	0.007	1000	4.17E+00	
Vanadium	8	0.008	1000	4.76E+00	
Zinc	150	0.15	1000	8.93E+01	4.55E+00
Uranium	10	0.01	1000	5.95E+00	
<b>Total Inorganics</b>	<b>178,943</b>	<b>1,325</b>	<b>135</b>	<b>1.06E+05</b>	<b>3.17E+04</b>
<b>Radionuclides</b>	<b>(pCi/L)</b>	<b>(pCi/L)</b>		<b>(mCi/yr)</b>	<b>(kg/yr)</b>
Alpha Activity	9	0.0225	400	5.35E+00	5.99E-01
Am-241	0.4	0.0004	1000	2.38E-01	3.33E-02
Beta Activity	40	0.1	400	2.38E+01	4.43E+01
Co-60	1	0.001	1000	5.95E-01	6.69E-03
H-3 (tritium)	400	400	1	0.00E+00	0.00E+00
Pu-239/240	0.2	0.0002	1000	1.19E-01	1.33E-02
Radium Total	0.2	0.002	100	1.18E-01	2.25E+00
Ru-106	4	0.004	1000	2.38E+00	1.34E-01
Sr-90	1	0.002	500	5.95E-01	1.11E+00
Uranium	8	0.008	1000	4.76E+00	8.89E-02
<b>Miscellaneous Parameters</b>	<b>(ppb)</b>	<b>(ppb)</b>		<b>(kg/yr)</b>	<b>(kg/yr)</b>
Alkalinity	60,000	600	100	3.54E+04	9.91E+00
Coliform (# per 100 mL)	230	230	1	0.00E+00	
Conductivity-field (µS)	250				
pH-field	9				
Suspended Solids	9,000	1	10000	5.36E+03	
Temperature-field (Celsius)	24				
Total Dissolved Solids	120,000	240	500	7.14E+04	1.60E+00
Turbidity (NTU)	N/A				

regeneration wastewater, which is sent to the evaporator, and periodically produces spent resin. The estimated quantities of secondary waste are listed in Table 5-2.

Table 5-2. Alternative 1: Secondary Wastes

Waste Description	Estimated Annual Mass	Estimated Annual Volume
Ion Exchange Resin*	3.08E+04 (kg)	4.27E+01 (m3)
Spent GAC**	1.08E+05 (kg)	6.72E+03 (m3)
Concentrated Wastewater ***	2.60E+06 (kg)	2.26E+03 (m3)
<b>TOTAL</b>	<b>2.73E+06 (kg)</b>	<b>9.02E+03 (m3)</b>

\*Waste ion exchange resin volume = annual replacement of one week supply of resin.  
 \*\*Spent GAC bulk density = 28 lb/cf or 448 kg/m3.  
 \*\*\*Concentrated Wastewater = 20% solids @ 1.74 specific gravity & 80% water @ 1.0 specific gravity.

The filters will be responsible for removing particles greater than 1 micron diameter. This particulate matter will likely include adsorbed heavy metals. When the filters are backflushed, the particles and the backflush water are discharged to the MVR evaporator.

Based on a usage of 5600 liters treated per kg of carbon (670 gal/lb), about 108,000 kg (236,000 lbs) of spent GAC will be produced annually by Alternative 1. Because the GAC removes the organic constituents from the wastewater, the spent GAC from this unit operation will be nearly saturated with organic compounds. The GAC could be classified as a dangerous waste based on Washington State designation. For costing purposes, it is assumed that the spent GAC will be regenerated in an off-site facility. The GAC could also be regenerated or disposed of at Hanford.

The regeneration of ion exchange resins produces liquid secondary wastes. An averaged flowrate of 15 lpm (4 gpm) of waste regeneration solution and rinse water will be generated. This is based on the assumption of 2 equivalents per liter resin capacity and 3 bed volumes of 1 molar acid and base regeneration solution for cation and anion exchange respectively. The waste regeneration solution will be sent to the MVR evaporator and the rinse water will be recycled to the treatment system.

Following concentration of the wastewater from the filters and ion exchange system to 20 percent solids, 2,260,000 liters (600,000 gal) of wastewater are produced annually. It is assumed that the aqueous secondary waste can be concentrated to 20% dissolved solids without significant crystallization. This solution can be sent to a hazardous waste treatment facility for stabilization and disposal.

An average of about 30,800 kg (67,800 pounds) per year of resin will be produced as the resin degrades and requires replacement. The degraded resin will first be regenerated and rinsed to remove residual ions. It is anticipated that this resin will not be classified as a dangerous waste. If so, the resin may be disposed of in a conventional solid waste landfill. Testing is required to ensure that the resin is indeed non-hazardous.

#### 5.1.4 Flexibility

Alternative 1 is highly flexible in its ability to treat variable contaminant loadings. Although some unit operations included in Alternative 1 are less flexible than others, there are ways of minimizing the impact of the variation, such as increasing the size of equipment to match the requirements of the maximum expected loading.

The presence of the holding tank in front of the process train is very significant because it provides equalization of the flow. The tank volume of 190,000 liters (50,000 gallons) provides an average hydraulic retention time of 2.8 hours. The optimum size of the holding tank is dependent on the variability of the flow, which has not yet been quantified, and on hydraulic mixing properties of the tank. Nonetheless, the variations in the loading are damped in the holding tank.

The filters have the potential to become fouled with fines and organic slime. This may be a greater problem with the temporary introduction of high solids loading. The potential for clogged filters is addressed two ways. First, the filters are purposely oversized and parallel, full-capacity trains are provided. This design allows a filter to operate at full capacity even when a second is out of service. Second, the filters are equipped with backflushing which can be set to activate when the filters reach a pre-determined level of blockage. If backflushing eventually fails to adequately clean the filters, the filter media or elements would be replaced.

GAC adsorption is a highly flexible unit operation. GAC systems are capable of adsorbing contaminants over a wide range of concentrations with removal efficiencies over 90 percent. Factors that limit the flexibility of GAC include competition between different compounds for adsorption sites and sensitivity to variable concentrations. Competition for adsorption sites may limit the removal of a particular compound that adsorbs to the GAC less strongly than other major contaminants. The sensitivity to variable concentrations can be a problem when high concentrations are followed by low concentrations. This sequence can also cause previously adsorbed material to desorb. Because the effluent quality from the GAC columns is monitored, these limitations do not imply that effluent water quality will suffer. However, these effects could result in more frequent changing of the GAC than would occur under static loading.

The ion exchange system, which removes dissolved ions, can be affected by variable loading. However, the system also can be designed to prevent failure. Ion exchange columns can easily treat waste streams with consistent loading. They can also handle increasing loadings well. However, when a period of high loading is followed by a period of low loading, the ion exchange resin tends to release captured ions. One simple method of preventing this problem is to place ion exchange columns in series. When the first column is

saturated, the succeeding column will capture residual ions. The second column acts as a back-up. The water between the serial columns is monitored to indicate when the first column requires regeneration. The design of Alternative 1 incorporates this configuration of ion exchange columns.

The MVR evaporator system will be a flexible system if the proper design and controls are used. A variable speed drive can be used on the compressor to vary operating pressure and loading conditions. Temperature, level, flow, and pressure controls are used to control the evaporator during operation with varying input conditions. For operating rate extremes, the evaporator can be operated in recirculation on hot standby to await fresh feed or, if conditions warrant, the evaporator can be shut down. The start-up of the evaporator will probably require a period of several hours to reach desired operating conditions. The evaporator would require over-sizing to accommodate increased secondary waste flow rates.

### 5.1.5 Reliability

Alternative 1 is a very reliable process. Most of the unit operations provide passive treatment with few moving parts. If components of the alternative were to fail, the likely result would be stopping or reducing the flow of water through the system rather than discharging contaminated water.

The filtration component of Alternative 1 operates passively. Thus, it is very reliable. The most common failure of filters is plugging. As discussed in the previous section, the filters are equipped with backflushing devices and are oversized and redundant, so stopping of the system flow because of plugging will be uncommon. Moreover, plugging will not result in releases of contaminated water, but will merely reduce the flow of water through the treatment system until the filters are backflushed or replaced.

Because GAC adsorption is a passive process, its reliability is very good. Also, the use of serial adsorption columns improves the reliability by capturing additional contamination that may temporarily pass the first column. The limitations of GAC adsorption discussed in Section 5.1.4 reduce the reliability. The extent of reduction depends upon the variability of the flow stream, particularly with respect to temperature. Nevertheless, the GAC process may be designed to accommodate the process fluctuations and achieve the desired level of treatment. Moreover, the temperature fluctuations are not expected to be large. The cost of gaining the added reliability under variable flow conditions is more frequent replacement of the GAC.

Ion exchange is also a passive process in this alternative. As long as the ion exchange resin is regenerated and replaced correctly, the system will work effectively. Monitoring of the water quality from the ion exchange columns is critical to establishing the schedule for regenerating and replacing the resin. Duplicate devices for monitoring conductivity of the effluent water before and after the first column may be necessary to ensure high water quality.

The MVR evaporator is a reliable piece of equipment. The only significant moving part on the evaporator is the compressor. These compressors typically operate with a low

head at a high flow rate and should present minimal reliability problems if they are constructed of the proper materials and are properly maintained. The remainder of the evaporator consists of pressure vessels and heat transfer surfaces. Scaling of the heat transfer surfaces can be a significant problem but can usually be controlled chemically, by controlling the operating conditions, and/or by monitoring heat transfer and scheduling cleaning of the heat transfer surface as needed. Corrosion of the pressure vessel walls, heat transfer surfaces, or compressor components can have a very detrimental impact on reliability. Care must be taken during the design phase to evaluate the corrosion problems associated with the material being processed and select materials of construction which will provide the necessary operating life. This is particularly important because interactions of components in solution can sometimes result in cumulative corrosive effects.

### 5.1.6 Safety

Potential safety hazards of Alternative 1 include those associated with handling strong chemicals and potential exposures to released wastes. Nevertheless, preventive measures are included to minimize potential hazards.

Strong acids and bases, such as sulfuric acid and sodium hydroxide, are used in the Alternative 1 treatment process. Care must be taken to contain and control releases of these substances. Tanks of incompatible materials are located apart from each other. Encased piping is used to dispense these substances in the appropriate vessels. Annular leak detection equipment can provide additional protection. Safety equipment will also be available in the event of a spill. The safety equipment will include neutralizing chemicals, venting equipment, alarms, and personal protective equipment. Thus, the hazards associated with the presence of hazardous materials is readily manageable.

GAC adsorption is a very safe process. Except for pumps, there are no moving parts. There are no air vents from which contaminants would be emitted under normal operating conditions. The GAC vessels are pressure vessels which would be pre-tested to ensure their integrity. One possible safety concern is the handling of spent GAC. The spent GAC will contain organic compounds and possibly small amounts of radionuclides. Biodegradation of organic compounds may result in the release of gases. Most of the handling of the spent GAC will be done mechanically, but technicians will need personal protective equipment. Nonetheless, accidental releases from the GAC vessels are not expected to be significant.

Fugitive releases of chemical wastes are a potential safety hazard. Liquid leaks are possible from process piping, pump seals, and process equipment. These possible sources are controlled by including design features which minimize releases such as gaskets on pipe fitting joints, seal-less pumps, and sumps to collect drips and drain the water for feeding to the MVR evaporator.

The evaporator system will contain a large quantity of water at its boiling point as well as steam and therefore presents the possibility of an explosion due to uncontrolled heat input or some other failure. Safety devices (pressure relief valves, high temperature, level and pressure alarms, etc.) will be incorporated as part of the design and should eliminate this potential. There is also the potential of scalding burns resulting from operator exposure to

leaking hot water and steam. A careful design and regular inspection and maintenance should reduce this potential.

Finally, there is potential for exposure to chemical wastes as a result of conducting maintenance. For example, pumps must be serviced and ion exchange resin must be replaced. The design of the equipment minimizes the potential for exposure, however. For example, each piece of process equipment includes a bypass line to isolate the equipment for servicing. Also, parts and reagents requiring replacement are designed to be easily removed or decontaminated prior to removal.

#### 5.1.7 Technical Viability

The unit operations of Alternative 1 are well-established technologies. They are fairly robust or simple, capable of treating many types of waste under conditions of variable loading. Pilot testing will also be conducted to modify and refine the treatment process prior to full-scale implementation. It is anticipated that shortcomings will be identified and corrected at that stage.

Filtration devices have been used in many different applications with success. Because filters rely on separation based primarily on size they perform well under most conditions, provided the correct materials and sizes are selected. The potential for plugging the pores of fine filters exists, however, which can limit the applicability of certain types of fine filters.

The use of GAC adsorption to remove organic constituents is a technically viable option for most of the compounds present. GAC has a long track record of use in treating contaminated water. However, it does not remove all the organic compounds present. Ethyl alcohol, ketones, and other organic compounds with high solubility in water do not adsorb well. Compounds such as chloroform adsorb sufficiently well to attain high removal efficiency, but require large amounts of activated carbon (1 kg per 8000 liters of water treated) to attain this level of treatment. GAC is a good technology for removing organic compounds as a class, but there are some compounds that do not adsorb well. Thus, removal of organic compounds will not be comprehensive.

Ion exchange is another process that is well-established. It is used in many applications for polishing and producing ultra-pure water. It removes a broad spectrum of ions. Problems using ion exchange usually result from inadequate pretreatment. Because the Alternative 1 ion exchange system is preceded by microfiltration, pretreatment should prove adequate. Ion exchange systems may exhibit a chromatographic separation of ions due to variable selectivity of the resin adsorption sites. This potential problem is overcome by designing the column for adequate removal of the compound of concern that is most poorly adsorbed and by installing columns in series with monitoring for breakthrough between the columns.

MVR evaporators are a well developed technology and are widely used to concentrate fruit juices and produce drinkable water from sea water. They have a high thermal efficiency but require a relatively large heat transfer area relative to other types of evaporators.

The process train is technically viable, using technologies that have been proven to be effective on the compounds of interest.

### 5.1.8 Capital and Operating Costs

The cost estimate for Alternative 1 is summarized in Table 5-3. The estimate is divided into process equipment costs, costs for other equipment and support, and operation and maintenance (O & M) costs. The project capital cost is calculated by applying cost factors to the process equipment capital cost. The cost factors were derived from the cost estimate made by Kaiser (1990) in the Conceptual Design Report for the equivalent of Alternative 2. This derivation is shown in Appendix A. The cost elements used by Kaiser were grouped into the categories used in the original BAT document (Engineering Science 1989). The costs associated with each category were ratioed to the capital equipment cost to obtain the desired cost factors. It should be noted that these costs are rough order-of-magnitude and should only be used for comparison of alternatives.

The process equipment costs are comprised of the filtration, GAC adsorption, ion exchange, and MVR evaporator unit operations. The total estimated process equipment cost is \$1,062,000. The total estimated capital cost is \$9,152,000 including administration, engineering, permitting, buildings, support equipment, and a contingency. The estimated annual O & M cost is \$12,100,000, about 75% of which is secondary waste disposal.

All secondary wastes, except for GAC, are assumed to require disposal on the Hanford Reservation. It is assumed that GAC is returned to the vendor for regeneration. The miscellaneous wastes such as spent ion exchange resin and filter media are assumed to be placed in an on-site landfill. Costs for landfilling are assumed to be similar to landfill of low-level waste at \$1911/m<sup>3</sup> (\$54/cf). The evaporator bottoms will likely be designated as a Dangerous Waste and require further processing prior to disposal. For costing purposes, it is assumed that the evaporator bottoms can be grouted directly and disposed in vaults. Costs for grouting liquids at Hanford are estimated at \$3963/m<sup>3</sup> (\$15/gal).

The present worth and equivalent uniform annualized cost (EUAC) of Alternative 1 are calculated using a 7 percent time value of money and a project life of 30 years. The estimated present worth is \$159 million and the EUAC is \$12.8 million.

### 5.1.9 Ease of Maintenance

Routine maintenance is required of several of the unit operations comprising Alternative 1. The filtration system, GAC adsorption, and ion exchange system have components that will be replaced on a regular basis. The treatment system design reflects the need to replace these parts with minimal effort.

The filter elements are designed to be automatically backwashed without human contact. In cases where an aggressive cleaning agent is required to remove deposits, special dispensers can supply the cleanser, again with no human contact. It is only when filter elements must be replaced that maintenance workers must be present. Prior to this handling, the filters will be thoroughly backwashed to minimize potential exposure hazards.

Table 5-3. Alternative 1: Cost Estimate

CAPITAL COST

1. Process Equipment			
A. Filtration (0.5 cu ft/day solids)			\$100,000
B. Ion Exchange System (6 - 150 cu ft columns, 300 gpm)			\$500,000
C. Granular Activated Carbon System (2 - 715 cu ft columns, 300 gpm)			\$212,000
D. MVR Evaporator System (5 gpm)			\$250,000
	Cost	Subtotal	<hr/> \$1,062,000
	Factor		
2. Auxillary Equipment	0.05		\$53,100
3. Installation	0.10		\$106,200
4. Diversion Basins			\$1,800,000
5. Instrumentation	0.08		\$84,960
6. Building	0.25		\$265,500
7. Facilities	0.15		\$159,300
8. Outside Lines			\$600,000
		Subtotal	<hr/> \$4,131,060
9. Engineering	0.27		\$1,115,386
Contract Administration	0.16		\$660,970
Project Management	0.15		\$619,659
		Subtotal	<hr/> \$6,527,075
Escalation	0.14		\$913,790
		Subtotal	<hr/> \$7,440,865
Contingency	0.23		\$1,711,399
		Project Cost	<hr/> \$9,152,264

NOTES:

- 1) Costs data were obtained from WHC-SD-LO45H-CDR-001 and vendor information.
- 2) Cost Factors derived from WHC-SD-LO45H-CDR-001.

Table 5-3. Alternative 1: Cost Estimate (cont.)

O & M COST		Annual Cost
1. Materials		
GAC		\$236,500
IX Resin		\$196,570
Sulfuric acid		\$107,400
Caustic soda		\$224,800
Evaporator electrical power		\$17,520
2. Manpower		
5 shifts@ 4 people/shift		\$2,000,000
3. Secondary Wastes		
GAC	236500 lb	\$236,500
On-site Landfill	43 m3	\$81,600
Grouted Liquid	2260 m3	\$8,956,380
TOTAL ANNUAL O&M COST		\$12,057,270

NOTES:

- 1) Material costs obtained from vendors
- 2) Manpower costs and secondary waste disposal costs obtained from WHC.
- 3) Utility costs were not included because they are a small percentage of the total O&M and they are similar between the alternatives.

Maintenance of the GAC columns requires GAC replacement, pump servicing, and routine inspection. None of these operations is considered technically difficult. GAC replacement involves hydraulically transferring the spent GAC to a holding tank, recharging the adsorption vessel, and transferring the spent GAC to a holding container or transport vehicle. Pump servicing and routine inspection are simple operations. Overall, the GAC adsorption component is relatively easy to maintain.

The ion exchange operation requires a number of maintenance activities. These activities include periodically replacing the resin, supplying acid and base for resin regeneration, and servicing pumps and other backwashing/regeneration equipment. About 10 to 30 percent of the resin must be replaced annually. The resin may be removed hydraulically and the resulting water-resin mixture can be easily dewatered by draining. The use of regeneration chemicals is a standard operation requiring no special procedures. Maintenance of the pumps and other equipment is also a standard operation, albeit one involving human contact, conducted annually.

Maintenance for the MVR evaporator will need to address three areas, wear on the compressor, scaling of the heat transfer surfaces, and corrosion of the pressure vessel walls and heat transfer surface areas. Compressor wear can be monitored by the use of appropriate sensors on the rotating elements and by visually inspecting components at regularly scheduled intervals. Scaling can be monitored by observing heat transfer performance over a period of time and noting any deterioration. If scale needs to be removed, cleaning of heat transfer surfaces may be required if other means are not successful in controlling scaling. Corrosion can be monitored by a careful nondestructive inspection program using ultrasonic thickness testing, acoustic emissions testing, X-ray inspection, and visual inspection. If corrosion rates are excessive or pitting develops, repairs will have to be made to the appropriate areas. None of these maintenance requirements are unusual or exceptional and should be relatively straightforward for a competent maintenance department to carry out.

## 5.2 ALTERNATIVE 2

Alternative 2 is similar to Alternative 1, differing in that reverse osmosis (RO) is added in front of the ion exchange component. Because of the similarities between the two alternatives, the reader is referred to Section 5.1 for discussion of the filtration, GAC adsorption, ion exchange, and secondary waste processes. Only the differences resulting from the inclusion of RO are discussed in this section.

### 5.2.1 Process Description

The primary train of Alternative 2 consists of four conventional water treatment operations: filtration, GAC adsorption, reverse osmosis, and ion exchange. Filtration removes suspended solids; GAC adsorption removes organic compounds; reverse osmosis removes large dissolved molecules and ions; and ion exchange removes dissolved ions. The process, as a whole, relies on the passive removal of compounds by separating them from the water. The compounds are captured on solid materials (filters, GAC, and resin) which

themselves become wastes requiring treatment or disposal. MVR evaporation concentrates secondary wastewater.

The first step in the process is filtering to remove suspended solids with a diameter above 1 micron. The filtration system used is essentially identical to that described in Alternative 1. The GAC adsorption process is also essentially the same. The ion exchange component of Alternative 2 is essentially equivalent to that of Alternative 1, although the loading of contaminants in the waste water fed to the ion exchange system is decreased. Due to the decreased contaminant loading, cation and anion exchange resins are combined in three mixed-bed ion exchange columns, rather than the six separate columns of Alternative 1.

Reverse osmosis (RO) follows the GAC adsorption step. The RO filters remove large dissolved molecules and ions which cannot pass the membrane pores. A two-stage RO system is used, with each stage removing about 95 percent of the ions and about 75 percent of organic materials. Two streams are produced from the RO system: a treated stream and a reject stream. The reject volume per stage is about 25 percent, resulting in an overall reject flow of about 76 lpm (20 gpm) and a treated flow of 1060 lpm (280 gpm). The reject stream will be sent to the MVR evaporator. Evaporation and other secondary waste treatment operations were described in Section 5.1.1.

### 5.2.2 Treated Water Quality

The estimated composition of the treated water exiting the Alternative 2 process train is shown in Table 5-4. The first column of numbers shows the untreated water quality. The second column shows concentrations of the specific compounds after treatment by the entire process train. The third column indicates the overall decontamination factor (DF) for the process train. The fourth column lists the total estimated quantity of the particular compounds that are removed annually. The final column tabulates the toxic mass removed.

It can be seen in Table 5-4 that about 90 to 99 percent of the organic compounds and greater than 99 percent of the inorganic compounds are removed.

### 5.2.3 Secondary Wastes

All of the unit operations comprising Alternative 2 produce secondary waste, either directly or indirectly: the filtration systems produce backflush water and occasionally used filter elements; the RO system generates spent RO membranes and produces a waste stream that is evaporated to produce concentrated waste; and the ion exchange system produces regeneration wastewater and spent resin. The estimated quantities of secondary waste are listed in Table 5-5.

The RO system will produce a waste stream of about 76 lpm (20 gpm), which contains about 0.28 percent solids. Another solid waste resulting from the RO process will be spent RO membranes. Assuming a membrane life of three years, it is estimated that 1.3 cubic meters of fouled RO membranes will be produced annually.

Table 5-4. Alternative 2: Treated Water Quality

Constituent	Design Influent Concentrations	Final Effluent Concentrations	Total Decontamination Factor	Total Mass Removed By System	Toxic Mass Removed by System
<u>Organic Compounds</u>	(ppb)	(ppb)		(kg/yr)	(kg/yr)
Acetone	70	0.88	80	4.12E+01	
Bisethanolethanedithiol	1	0.01	100	5.90E-01	
Bis(ethylhexyl)phthalate	80	0.04	2000	4.77E+01	8.91E+01
2-Butoxyethanol	1	0.01	100	5.90E-01	
2-(2-butoxy ethoxy) ethanol	100	1.00	100	5.90E+01	
Chlorodifluoromethane	20	0.20	100	1.18E+01	
Chloroform	40	0.20	200	2.37E+01	7.00E+02
1,1-Dichloroethane	40	0.08	500	2.38E+01	
Dichlorodifluoromethane	3	0.03	100	1.77E+00	
Ethyl alcohol	3	0.03	100	1.77E+00	
Halogenated hydrocarbons	9	0.09	100	5.31E+00	
Methyl ethyl ketone	5	0.05	100	2.95E+00	
Methylene chloride	4	0.03	150	2.37E+00	
m-Xylene	1	0.002	500	5.95E-01	
o-p-Xylene	1	0.002	500	5.95E-01	
Purgable Organic Halides (POX)	6	0.01	500	3.57E+00	
2-Propanol	4	0.01	500	2.38E+00	
Tetrachloroethylene	10	0.02	500	5.95E+00	4.17E+01
Total Organic Carbon (TOC)	6,000	60.00	100	3.54E+03	
Toluene	2	0.004	500	1.19E+00	4.66E-04
Total Carbon	14,000	140.00	100	8.26E+03	
Total Organic Halides (TOX)	200	2.00	100	1.18E+02	
1,1,1-Trichloroethane	10	0.01	1000	5.95E+00	1.81E-03
Trichloroethene	0.4	0.0008	500	2.38E-01	1.54E-02
Trichloromonofluoromethane	1	0.01	100	5.90E-01	
Unknown	50	50.00	1	0.00E+00	
Unknown aliphatic HC	3	0.06	50	1.75E+00	
Unknown amide	2	0.04	50	1.17E+00	
Unknown amine	10	0.20	50	5.84E+00	
Unknown aromatic HC	4	0.02	200	2.37E+00	
Unknown fatty acid	30	0.60	50	1.75E+01	
Unknown fatty acid ester	1	0.02	50	5.84E-01	
Unknown PAH	40	0.80	50	2.34E+01	4.67E+04
<u>Inorganic Compounds</u>	(ppb)	(ppb)		(kg/yr)	(kg/yr)
Aluminum	350	0.02	20000	2.09E+02	
Ammonia	400	0.01	40000	2.38E+02	6.37E-01
Arsenic	10	0.0025	4000	5.96E+00	1.52E+04
Barium	60	0.0012	50000	3.58E+01	2.00E-01
Beryllium	30	0.0038	8000	1.79E+01	1.47E+04
Boron	25	0.0005	50000	1.49E+01	
Bromide	4	0.0020	2000	2.38E+00	
Cadmium	10	0.0005	20000	5.96E+00	3.37E-01
Calcium	30,000	1.50	20000	1.79E+04	
Chloride	60,000	30.00	2000	3.57E+04	
Chromium	10	0.0001	100000	5.96E+00	8.28E-01
Copper	80	0.0008	100000	4.77E+01	2.23E-01

Table 5-4. Alternative 2: Treated Water Quality (cont.)

Constituent	Design Influent Concentrations	Final Effluent Concentrations	Total Decontamination Factor	Total Mass Removed By System	Toxic Mass Removed by System
	(ppb)	(ppb)		(kg/yr)	(kg/yr)
Cyanide	50	0.03	2000	2.98E+01	3.28E+01
Fluoride	200	0.10	2000	1.19E+02	
Iron	600	0.03	20000	3.58E+02	8.69E+00
Lead	60	0.003	20000	3.58E+01	6.65E+01
Lithium	30	0.02	2000	1.79E+01	
Magnesium	5,000	0.25	20000	2.98E+03	
Manganese	60	0.00060	100000	3.58E+01	4.01E+00
Mercury	3	0.00003	100000	1.79E+00	9.05E+02
Nickel	60	0.00060	100000	3.58E+01	1.70E+01
Nitrate	6,000	3.00	2000	3.57E+03	2.00E+00
Nitrite	400	0.20	2000	2.38E+02	
Phosphate	1,000	0.25	4000	5.96E+02	
Potassium	1,000	0.50	2000	5.96E+02	
Selenium	6	0.0003	20000	3.58E+00	2.57E+00
Silicon	3,000	0.30	10000	1.79E+03	
Silver	20	0.001	20000	1.19E+01	5.70E+02
Sodium	40,000	20.00	2000	2.38E+04	
Strontium	100	0.01	20000	5.96E+01	
Sulfate	30,000	0.60	50000	1.79E+04	
Sulfide	100	0.01	10000	5.96E+01	1.67E+02
Tin	100	0.0050	20000	5.96E+01	
Titanium	7	0.0004	20000	4.17E+00	
Vanadium	8	0.0008	10000	4.77E+00	
Zinc	150	0.0015	100000	8.94E+01	4.55E+00
Uranium	10	0.0001	100000	5.96E+00	
<b>Total Inorganics</b>	<b>178,943</b>	<b>56.84</b>	<b>3148</b>	<b>1.07E+05</b>	<b>3.18E+04</b>
<b>Radionuclides</b>	<b>(pCi/L)</b>	<b>(pCi/L)</b>		<b>(mCi/yr)</b>	<b>(kg/yr)</b>
Alpha Activity	9.00	1.13E-03	8000	5.36E+00	5.80E-01
Am-241	0.40	4.00E-06	100000	2.38E-01	3.15E-02
Beta Activity	40.00	5.00E-03	8000	2.38E+01	4.53E+01
Co-60	1.00	5.00E-05	20000	5.96E-01	6.70E-03
H-3 (tritium)	400.00	4.00E+02	1	0.00E+00	0.00E+00
Pu-239/240	0.20	2.00E-06	100000	1.19E-01	1.33E-02
Radium Total	0.20	1.00E-04	2000	1.19E-01	2.23E+00
Ru-106	4.00	4.00E-05	100000	2.38E+00	1.34E-01
Sr-90	1.00	2.00E-05	50000	5.96E-01	1.13E+00
Uranium	8.00	8.00E-05	100000	4.77E+00	8.87E-02
<b>Miscellaneous Parameters</b>	<b>(ppb)</b>	<b>(ppb)</b>		<b>(kg/yr)</b>	<b>(kg/yr)</b>
Alkalinity	60,000	30	2000	3.57E+04	1.00E+01
Coliform (# per 100 mL)	230	12	20	1.30E+02	
Conductivity-field (µS)	250				
pH-field	9				
Suspended Solids	9,000	0.0009	10000000	5.36E+03	
Temperature-field (Celsius)	24				
Total Dissolved Solids	120,000	60	2000	7.15E+04	1.60E+00
Turbidity (NTU)	N/A				

Table 5-5. Alternative 2: Secondary Wastes

Waste Description	Estimated Annual Mass	Estimated Annual Volume
Ion Exchange Resin*	1.01E+03 (kg)	1.40E+00 (m3)
Spent GAC**	1.08E+05 (kg)	6.72E+03 (m3)
RO membranes	1.02E+02 (kg)	1.27E+00 (m3)
Concentrated Wastewater***	5.60E+05 (kg)	4.87E+02 (m3)
<b>TOTAL</b>	<b>6.69E+05 (kg)</b>	<b>7.21E+03 (m3)</b>

\*Waste ion exchange resin volume = annual replacement of one week supply of resin

\*\*GAC bulk density = 28 lb/cf or 448 kg/m<sup>3</sup>

\*\*\*Concentrated Wastewater = 20% solids @ 1.74 specific gravity & 80% water @ 1.0 specific gravity

Much less spent ion exchange resin is produced by Alternative 2 than Alternative 1, 1010 kg versus 30,800 kg, because the RO system reduces the ion exchange loading.

Assuming the secondary waste water is concentrated to about 20 percent solids, the annual volume of waste resulting from the RO reject, the ion exchange regeneration, and the filter backwash water will be about 643,000 liters (170,000 gal).

#### 5.2.4 Flexibility

The flexibility of filtration, GAC adsorption, ion exchange, and MVR evaporation has been discussed in Alternative 1.

An RO system is often not well-suited to handling variable loading. RO membranes are susceptible to fouling, which reduces their ability to pass clean water. Fouling does not reduce treated water quality, but it does reduce the volume of clean water passed by the membranes. One method of preventing these possible problems is to oversize the RO system by increasing the RO membrane area. A second solution is to pretreat the water before it reaches the RO system. This aim is one reason for placing the filtration and GAC adsorption in advance of the RO system. Thus, although the RO system may not handle variable loading well, there is sufficient pretreatment and over-sizing to ensure adequate performance.

#### 5.2.5 Reliability

The reliability of the components of Alternative 2, except RO, has been discussed in Section 5.1.5, to which the reader is referred.

RO filtration uses a physical separation to effect treatment. Its major mode of failure is fouling of membranes. Nevertheless, there are ways to reduce the fouling. As with filtration, fouling is reduced by over-sizing the equipment. Also, pre-filtration removes much of the material that would foul the membrane. GAC adsorption also may help reduce fouling of the RO membranes by removing organic contaminants; however, care must be taken to control GAC fines which could reach the RO system. It is important to note that if fouling does occur, it will reduce the capacity of the RO system, but does not result in poorer water quality. Electrical power is needed to drive high-pressure pumps that circulate wastewater in the RO system, so the process is dependent on the reliability of the pumps as well as the electrical supply.

#### **5.2.6 Safety**

High pressure pumps required to feed the RO system would present potential hazards to any one working in the vicinity of the system. The system would be designed to restrict the presence of workers near the RO system, however. Safety issues concerning the other components of Alternative 2 have been discussed in Section 5.1.6.

#### **5.2.7 Technical Viability**

The technical viability of filtration, GAC adsorption, and ion exchange was addressed in Section 5.1.7. This section addresses the technical viability of RO in this section.

RO devices have been used in many different applications where high quality water is needed. They are commonly used in desalination plants. RO devices have a relatively short, but reliable history in producing ultra-pure water. Their success depends on selecting the right type of membrane, sizing the system correctly, providing filtration in advance of the RO system, and cleaning the RO membranes regularly.

#### **5.2.8 Capital and Operating Costs**

The cost estimate for Alternative 2 is summarized in Table 5-6. The estimate is divided into process equipment costs, costs for other equipment and support, and operation and maintenance (O & M) costs.

The process equipment costs are comprised of the filtration, GAC adsorption, reverse osmosis, ion exchange, and MVR evaporator unit operations. The total estimated process equipment cost is \$1,733,000. The total estimated capital cost is \$11,600,000 including administration, engineering, permitting, buildings, support equipment, and a contingency. The estimated annual O & M cost is \$4,600,000, about 90% of which is operating labor and 40% secondary waste disposal.

The estimated present worth and EUAC of Alternative 2 are \$69 million and \$5.6 million, respectively.

Table 5-6. Alternative 2: Cost Estimate

CAPITAL COST

1. Process Equipment			
A. Filtration (0.5 cu ft/day solids)			\$100,000
B. Granular Activated Carbon System (2 - 715 cu ft columns, 300 gpm)			\$212,000
C. Reverse Osmosis (2 stage, 10% reject vol., 350 gpm)			\$571,000
D. Ion Exchange System (3 - 150 cu ft columns, 300 gpm)			\$300,000
E. MVR Evaporator System (25 gpm)			\$550,000
	Cost Factor	Subtotal	\$1,733,000
2. Auxillary Equipment	0.05		\$86,650
3. Installation	0.10		\$173,300
4. Diversion Basins			\$1,800,000
5. Instrumentation	0.08		\$138,640
6. Building	0.25		\$433,250
7. Facilities	0.15		\$259,950
8. Outside Lines			\$600,000
		Subtotal	\$5,224,790
9. Engineering	0.27		\$1,410,693
Contract Administration	0.16		\$835,966
Project Management	0.15		\$783,719
		Subtotal	\$8,255,168
Escalation	0.14		\$1,155,724
		Subtotal	\$9,410,892
Contingency	0.23		\$2,164,505
		Project Cost	\$11,575,397

NOTES:

- 1) Costs data were obtained from WHC-SD-LO45H-CDR-001 and vendor information.
- 2) Cost Factors derived from WHC-SD-LO45H-CDR-001.

Table 5-6. Alternative 2: Cost Estimate (cont.)

O & M COST		Annual Cost
1. Materials		
GAC		\$236,500
RO membranes		\$20,000
IX Resin		\$7,105
Sulfuric acid		\$3,200
Caustic soda		\$9,000
Evaporator electrical power		\$175,200
2. Manpower		
5 shifts@ 4 people/shift		\$2,000,000
3. Secondary Wastes		
GAC	236500 lb	\$236,500
On-site Landfill	2.7 m3	\$5,102
Grouted Liquid	487 m3	\$1,929,981
TOTAL ANNUAL O&M COST		\$4,622,588

NOTES:

- 1) Material costs obtained from vendors.
- 2) Manpower costs and secondary waste disposal costs obtained from WHC.
- 3) Utility costs were not included because they are a small percentage of the total O&M and they are similar between the alternatives.

### 5.2.9 Ease of Maintenance

The RO system must be maintained regularly, but this procedure is not difficult. The primary maintenance requirements include the replacement of membrane modules and the servicing of high pressure pumps. About every year, roughly one-third of the membranes are replaced. This operation requires handling of the membranes. Special handling may be needed because of minor chemical waste hazards, but mechanically the replacement involves only changing membrane cartridges, an operation requiring only a few minutes per cartridge. Pump servicing, consisting of lubrication and replacement of seals would be conducted about once a year.

The maintenance of the other process components was discussed in Section 5.1.9. One modification is that less ion exchange resin must be regenerated and replaced because the contaminant loading to the ion exchange columns is greatly reduced.

## 5.3 ALTERNATIVE 3

### 5.3.1 Process Description

Alternative 3 is very similar to Alternative 2; the primary difference is that UV/oxidation is substituted for GAC as the treatment for organic compounds.

UV/oxidation follows the filtration step. UV/oxidation destroys organic compounds through a combination of the ultraviolet light and the chemical oxidizing power of hydrogen peroxide and/or ozone. There are a number of different configurations of UV/oxidation systems depending on the order in which the waste water is exposed to the UV light and the chemical oxidants used. Contaminant destruction increases with longer residence time, higher UV power, and increased oxidant dose. Lower pH improves the destruction efficiency of some compounds, but no generalization can be made regarding the optimum pH for a complex mixture of organic compounds such as expected in the 300 areas wastewater.

A contact time of about 15 to 30 minutes is provided in the UV/oxidation reaction vessel, requiring a tank volume of about 17 to 34 cubic meters (4500 to 9000 gallons). Chemical oxidant doses are about five to ten times the theoretical requirements because of interferences and oxidation of non-target compounds. Power requirements for the UV lamps are up to about 0.8 kW per lpm of water flow. Thus, up to 900 kW of UV lamp power may be needed.

### 5.3.2 Treated Water Quality

The composition of the treated water resulting from Alternative 3 is tabulated in Table 5-7. In comparison to Alternative 2, the removal of some organic compounds is increased slightly because of the substitution of the UV/oxidation for GAC adsorption. UV/oxidation generally destroys water soluble organic compounds, such as acetone and 2-(2-butoxy ethoxy) ethanol, more effectively than does GAC adsorption. However, GAC adsorption is better at removing saturated chlorinated hydrocarbons with higher molecular weight, such as 1,1 dichloroethane and 1,1,1 trichloroethane.

Table 5-7. Alternative 3: Treated Water Quality

Constituent	Design Influent Concentrations	Final Effluent Concentrations	Total Decontamination Factor	Total Mass Removed By System (kg/yr)	Toxic Mass Removed By System (kg/yr)
<u>Organic Compounds</u>					
	(ppb)	(ppb)		(kg/yr)	(kg/yr)
Acetone	70	0.18	400	4.16E+01	
Bisethanolethanedithiol	1	0.01	100	5.90E-01	
Bis(ethylhexyl)phthalate	80	0.04	2000	4.77E+01	8.91E+01
2-Butoxyethanol	1	0.01	100	5.90E-01	
2-(2-butoxy ethoxy) ethanol	100	1.00	100	5.90E+01	
Chlorodifluoromethane	20	2.00	10	1.07E+01	
Chloroform	40	2.00	20	2.26E+01	6.68E+02
1,1-Dichloroethane	40	4.00	10	2.15E+01	
Dichlorodifluoromethane	3	0.30	10	1.61E+00	
Ethyl alcohol	3	0.03	100	1.77E+00	
Halogenated hydrocarbons	9	0.18	50	5.26E+00	
Methyl ethyl ketone	5	0.01	500	2.97E+00	
Methylene chloride	4	0.67	6	1.99E+00	
m-Xylene	1	0.002	500	5.95E-01	
o-,p-Xylene	1	0.002	500	5.95E-01	
Purgable Organic Halides (POX)	6	0.12	50	3.50E+00	
2-Propanol	4	0.01	500	2.38E+00	
Tetrachloroethylene	10	0.02	500	5.95E+00	4.17E+01
Total Organic Carbon (TOC)	6,000	60.00	100	3.54E+03	
Toluene	2	0.004	500	1.19E+00	4.66E-04
Total Carbon	14,000	280.00	50	8.18E+03	
Total Organic Halides (TOX)	200	4.00	50	1.17E+02	
1,1,1-Trichloroethane	10	0.10	100	5.90E+00	1.79E-03
Trichloroethene	0.4	0.0008	500	2.38E-01	1.54E-02
Trichloromonofluoromethane	1	0.10	10	5.36E-01	
Unknown	50	50.00	1	0.00E+00	
Unknown aliphatic HC	3	0.06	50	1.75E+00	
Unknown amide	2	0.04	50	1.17E+00	
Unknown amine	10	0.20	50	5.84E+00	
Unknown aromatic HC	4	0.002	2000	2.38E+00	
Unknown fatty acid	30	0.60	50	1.75E+01	
Unknown fatty acid ester	1	0.02	50	5.84E-01	
Unknown PAH	40	0.80	50	2.34E+01	4.67E+04
<u>Inorganic Compounds</u>					
	(ppb)	(ppb)		(kg/yr)	(kg/yr)
Aluminum	350	0.02	20000	2.09E+02	
Ammonia	400	0.20	2000	2.38E+02	6.36E-01
Arsenic	10	0.0025	4000	5.96E+00	1.52E-04
Barium	60	0.0012	50000	3.58E+01	2.00E-01
Beryllium	30	0.0038	8000	1.79E+01	1.47E-04
Boron	25	0.0005	50000	1.49E+01	
Bromide	4	0.0020	2000	2.38E+00	
Cadmium	10	0.0005	20000	5.96E+00	3.37E-01
Calcium	30,000	1.50	20000	1.79E+04	
Chloride	60,000	30.00	2000	3.57E+04	
Chromium	10	0.0001	100000	5.96E+00	8.28E-01
Copper	80	0.0008	100000	4.77E+01	2.23E-01

Table 5-7. Alternative 3: Treated Water Quality (cont.)

Constituent	Design Influent Concentrations	Final Effluent Concentrations	Total Decontamination Factor	Total Mass Removed By System	Toxic Mass Removed By System
	(ppb)	(ppb)		(kg/yr)	(kg/yr)
Cyanide	50	0.03	2000	2.98E+01	3.28E+01
Fluoride	200	0.10	2000	1.19E+02	
Iron	600	0.03	20000	3.58E+02	8.69E+00
Lead	60	0.003	20000	3.58E+01	6.65E+01
Lithium	30	0.02	2000	1.79E+01	
Magnesium	5,000	0.25	20000	2.98E+03	
Manganese	60	0.00060	100000	3.58E+01	4.01E+00
Mercury	3	0.00003	100000	1.79E+00	9.05E+02
Nickel	60	0.00060	100000	3.58E+01	1.70E+01
Nitrate	6,000	3.00	2000	3.57E+03	2.00E+00
Nitrite	400	0.20	2000	2.38E+02	
Phosphate	1,000	0.25	4000	5.96E+02	
Potassium	1,000	0.50	2000	5.96E+02	
Selenium	6	0.0003	20000	3.58E+00	2.57E+00
Silicon	3,000	0.30	10000	1.79E+03	
Silver	20	0.001	20000	1.19E+01	5.70E+02
Sodium	40,000	20.00	2000	2.38E+04	
Strontium	100	0.01	20000	5.96E+01	
Sulfate	30,000	0.60	50000	1.79E+04	
Sulfide	100	0.01	10000	5.96E+01	1.67E+02
Tin	100	0.0050	20000	5.96E+01	
Titanium	7	0.0004	20000	4.17E+00	
Vanadium	8	0.0004	20000	4.77E+00	
Zinc	150	0.0015	100000	8.94E+01	4.55E+00
Uranium	10	0.0001	100000	5.96E+00	
<b>Total Inorganics</b>	<b>178,943</b>	<b>57.03</b>	<b>3138</b>	<b>1.07E+05</b>	
<b>Radionuclides</b>	<b>(pCi/L)</b>	<b>(pCi/L)</b>		<b>(mCi/yr)</b>	<b>(kg/yr)</b>
Alpha Activity	9.00	1.13E-03	8000	5.36E+00	5.80E-01
Am-241	0.40	4.00E-06	100000	2.38E-01	3.15E-02
Beta Activity	40.00	5.00E-03	8000	2.38E+01	4.53E+01
Co-60	1.00	5.00E-05	20000	5.96E-01	6.70E-03
H-3 (tritium)	400.00	4.00E+02	1	0.00E+00	0.00E+00
Pu-239/240	0.20	2.00E-06	100000	1.19E-01	1.33E-02
Radium Total	0.20	1.00E-04	2000	1.19E-01	2.23E+00
Ru-106	4.00	4.00E-05	100000	2.38E+00	1.34E-01
Sr-90	1.00	2.00E-05	50000	5.96E-01	1.13E+00
Uranium	8.00	8.00E-05	100000	4.77E+00	8.87E-02
<b>Miscellaneous Parameters</b>	<b>(ppb)</b>	<b>(ppb)</b>		<b>(kg/yr)</b>	<b>(kg/yr)</b>
Alkalinity	60,000	30.00	2000	3.57E+04	1.00E+01
Coliform (# per 100 mL)	230	0.12	2000	1.37E+02	
Conductivity-field (µS)	250				
pH-field	9				
Suspended Solids	9,000	0.0009	10000000	5.36E+03	
Temperature-field (Celsius)	24				
Total Dissolved Solids	120,000	60.00	2000	7.15E+04	1.60E+00
Turbidity (NTU)	N/A				

Most of the inorganic compounds are not affected significantly by UV/oxidation. Thus, the removal of inorganic compounds is nearly the same in Alternative 3 as in Alternative 2, exceeding 99 percent in both cases.

### 5.3.3 Secondary Wastes

Secondary wastes produced by Alternative 3 are listed in Table 5-8. Filter elements, RO membranes, spent ion exchange resin, and solid waste from the evaporator are produced as they are in Alternative 2. The waste quantities generated by these two alternatives are similar. The use of UV/oxidation instead of GAC adsorption eliminates the production of spent GAC. Failed UV lamps must also be disposed of.

Table 5-8. Alternative 3: Secondary Wastes

Waste Description	Estimated Annual Mass	Estimated Annual Volume
Ion Exchange Resin*	1.02E+03 (kg)	1.41E+00 (m3)
RO membranes	1.02E+02 (kg)	1.27E+00 (m3)
Concentrated Wastewater**	5.60E+05 (kg)	4.87E+02 (m3)
<b>TOTAL</b>	<b>5.61E+05 (kg)</b>	<b>4.90E+02 (m3)</b>

\*Waste ion exchange resin volume = annual percentage replacement of one week supply of resin  
 \*\*Concentrated Wastewater = 20% solids @ 1.74 specific gravity & 80% water @ 1.0 specific gravity

### 5.3.4 Flexibility

The flexibility of all the components of Alternative 3, except the UV/oxidation system, has been discussed in Sections 5.1.4 and 5.2.4.

The UV/oxidation system may be sensitive to variations in contaminant loading, but this sensitivity may be countered by over-designing the system. A UV/oxidation system is generally designed with a certain contaminant concentration in mind. Because of the expected variable loading, one sizes the system for the maximum expected dose. Also, the UV and chemical oxidants may not preferentially attack the target compounds and inorganic compounds may react with the oxidant. To counter these inefficiencies, the dosages of oxidant and the lamp power are increased. The result of this over-design is that when high contaminant loadings occur, they are treated effectively; when lower loadings occur, excess oxidant and electrical power are applied, resulting in higher operating costs.

### 5.3.5 Reliability

The reliability of the filters, RO, and ion exchange components of Alternative 3 has been discussed in Sections 5.1.5 and 5.2.5.

The UV/oxidation step of Alternative 3 is probably the least reliable, but its potential for failure is still minimal. UV/oxidation requires a continual supply of electrical power and chemical oxidant. Electrical supply and chemical dispensing systems are routinely used and highly reliable. Quartz sleeves around the UV lamps must be routinely cleaned to prevent fouling with light-absorbing materials. If hydrogen peroxide is used as a chemical oxidant, then a sufficient supply must be stored to out-last possible supply interruptions. If ozone is used, then the electrical power must be maintained and the ozone generator must be serviced regularly and a back-up unit must be available.

### 5.3.6 Safety

In addition to minor safety concerns associated with the filtration, RO, and ion exchange systems, as discussed in previous sections, there are safety issues surrounding the use and maintenance of the UV/oxidation system. These issues include the use of a potent chemical oxidant and the use of UV lamps, both of which present health risks to potentially-exposed workers. Nonetheless, the UV/oxidation system is designed to prevent releases of UV light and oxidant, and excess oxidant is catalytically destroyed. Care must also be taken in handling the chemical oxidant. The oxidant must be kept away from combustible materials, a factor taken into consideration during final design. Maintenance of the UV/oxidation system poses little safety concern because the oxidants persist for only a few minutes after the power and oxidant source is shut down.

### 5.3.7 Technical Viability

The technical viability of most of the components of Alternative 3, except the UV/oxidation component, has been discussed in Sections 5.1.7 and 5.2.7.

The UV/oxidation system probably is the least-proven component. The combination of UV light and chemical oxidant provides very aggressive conditions for treatment of organic compounds. However, inorganic ions may interfere with treatment and some low molecular weight, saturated organic molecules (chloroform, for example) resist oxidation. Also, different organic compounds will be treated with varying efficiencies depending on pH, temperature, and other process parameters. Conditions favoring treatment of one compound may hinder treatment of a second. Nonetheless, UV/oxidation treats a broad spectrum of organic compounds and increasing UV power, oxidant dosing, and retention time can improve the extent of treatment. Pilot testing will help optimize the effectiveness of the UV/oxidation component.

### 5.3.8 Capital and Operating Costs

The cost estimate for Alternative 3 is summarized in Table 5-9. The estimate is divided into process equipment costs, costs for other equipment and support, and operation

Table 5-9. Alternative 3: Cost Estimate

CAPITAL COST

1. Process Equipment			
A. Filtration (0.5 cu ft/day solids)			\$100,000
B. UV Oxidation System			\$1,000,000
C. Reverse Osmosis			\$571,000
(2 stage, 10% reject vol., 350 gpm)			
D. Ion Exchange System			\$300,000
(3 - 150 cu ft columns, 300 gpm)			
E. MVR Evaporator System (25 gpm)			\$550,000
	Cost	Subtotal	\$2,521,000
	Factor		
2. Auxillary Equipment	0.05		\$126,050
3. Installation	0.10		\$252,100
4. Diversion Basins			\$1,800,000
5. Instrumentation	0.08		\$201,680
6. Building	0.25		\$630,250
7. Facilities	0.15		\$378,150
8. Outside Lines			\$600,000
		Subtotal	\$6,509,230
9. Engineering	0.27		\$1,757,492
Contract Administration	0.16		\$1,041,477
Project Management	0.15		\$976,385
		Subtotal	\$10,284,583
Escalation	0.14		\$1,439,842
		Subtotal	\$11,724,425
Contingency	0.23		\$2,696,618
		Project Cost	\$14,421,043

NOTES:

- 1) Costs for process equipment, diversion basins, and outside lines were obtained from WHC-SD-L045H-CDR-001 and vendor information.
- 2) Cost Factors derived from WHC-SD-LO45H-CDR-001.
- 3) UV Oxidation equipment cost estimated from vendor information.

Table 5-9. Alternative 3: Cost Estimate (cont.)

O & M COST		Annual Cost
1. Materials		
Sulfuric acid		\$3,200
Caustic soda		\$9,000
UV Bulbs		\$120,000
Electric Power for UV Oxidation system (\$0.04/kwh)		\$229,862
IX Resin		\$7,131
RO membranes		\$20,000
Evaporator electrical power		\$175,200
2. Manpower		
5 shifts @ 4 people/shift		\$2,000,000
3. Secondary Wastes		
On-site Landfill	2.68 m3	\$5,121
Grouted Liquid	487 m3	\$1,929,981
TOTAL ANNUAL O&M COST		\$4,499,496

NOTES:

- 1) Material costs obtained from vendors.
- 2) Manpower costs and secondary waste disposal costs obtained from WHC.
- 3) Utility costs were not included because they are a small percentage of the total O&M and they are similar between the alternatives.
- 4) Power requirements were added for UV bulbs because they are significant for this alternative.

and maintenance (O & M) costs.

The process equipment costs are comprised of the filtration, UV/oxidation, reverse osmosis, ion exchange, and MVR evaporator unit operations. The total estimated process equipment cost is \$2,500,000. The total estimated capital cost is \$14,400,000 including administration, engineering, permitting, buildings, support equipment, and a contingency. The estimated annual O & M cost is \$4,500,000, about 40% of which is operating labor and 40% is secondary waste disposal.

The estimated present worth and EUAC are \$70 million and \$5.6 million, respectively, of Alternative 3.

### 5.3.9 Ease of Maintenance

Except for the UV/oxidation unit operation, the maintenance requirements of the Alternative 3 components have been covered in Sections 5.1.9 and 5.2.9.

Maintenance requirements for the UV/oxidation system include replacing UV lamps, replacing air filters on the ozonator and changing air dryer desiccant (if ozone is used), and replacement of miscellaneous electrical and control parts. Replacing the UV lamps is comparable in ease to replacing tubular fluorescent lights. The power supply is shut down, the old lamp is disconnected and replaced, and power is restored. Cleaning ozonator air filters is also a simple operation, and is performed about once a year.

## 5.4 ALTERNATIVE 4

### 5.4.1 Process Description

Alternative 4 consists of chemical coprecipitation, clarification, filtration, and GAC adsorption. Ion exchange is included as a standby process for treating potential excursions of heavy metal concentrations. Thus, ion exchange would be used only intermittently. Because the GAC component of Alternative 4 has been discussed in Section 5.1.1 the reader is referred that section for details. The discussion of the remaining components follows.

The chemical coprecipitation process relies on the precipitation of iron oxyhydroxide to remove heavy metal contamination. In this process, an iron salt solution is added to the wastewater along with a base such as a sodium hydroxide solution. Aeration may also be used to effect the precipitation. A mixed iron oxide solid precipitates from solution, incorporating other heavy metal ions into the solid matrix. This iron precipitate adsorbs increasing amounts of heavy metals as the solution pH is increased from about 5 to about 9.

The iron solid must then be removed from solution. A clarifier is used for this purpose. The settled solids collected from the bottom of the clarifier are pumped to a filter press which dewateres the solid. Some of the settled solids may be recycled to the precipitation vessel for additional heavy metals removal. The solid removed from the treatment train is tested using the TCLP test to determine if it is chemically hazardous. If it

is non-hazardous, the solid waste may be disposed in a standard landfill. If it is chemically hazardous, it may be treated or disposed in a RCRA-permitted disposal facility.

The clarified effluent is passed through a sand filter to remove residual iron solids. Two sand filters will be present, one in operation and the second on standby. The sand filter will be sized to remove particles larger than about 1 micron. The filters will include automatic backwash systems triggered by measured pressure drops across the filter. The backwashed water will be returned to the clarifier.

The final continuous treatment component is GAC adsorption. This unit operation is used to remove organic compounds. The size and operation of the GAC adsorption system are as described in Alternative 1.

An ion exchange system is included as a stand-by component. Its primary purpose is to treat possible excursions of metal concentrations. The ion exchange system includes both anion and cation exchange units, similar in size to those of Alternative 1. Because the use of the ion exchange units is anticipated to be infrequent, the ion exchange system of Alternative 4 does not include a regeneration system. Rather, the spent resin is disposed of in accordance with applicable requirements.

#### 5.4.2 Treated Water Quality

The composition of the treated water resulting from Alternative 4 is compiled in Table 5-10. It resembles that of Alternative 1 with respect to organic constituents, providing 90 to 99 percent removal. The concentration of heavy metals is about the same as results from alternatives employing ion exchange. However, the other inorganic ions are not significantly removed from solution. The concentration of sulfate increases because it is assumed that ferrous sulfate is added to the solution to effect co-precipitation. Note that the effluent water quality does not take into account occasional treatment provided by the standby ion exchange system. The DF's for inorganics were based on proof-of-concept testing by Unocal (Ebasco 1991a).

#### 5.4.3 Secondary Wastes

The quantities of secondary wastes produced by Alternative 4 are listed in Table 5-11. The amount of spent GAC is comparable to the amounts produced by Alternative 1, about 108,000 kg (236,000 lb). The ion exchange step in Alternative 4 is used infrequently, but there is no provision for regeneration of the resin. The result is about 4.27 cubic meters or 3,080 kg (6,780 lb) of spent resin produced annually. For purposes of estimating the metal sludge generated, the following assumptions were made: 5 ppm of iron will be added; 50 percent of the solids produced will be recycled; and the dewatered solids from the filter press will have a solids concentration of 35 percent. The resulting estimate is 68,300 kg (150,000 lb) of metal sludge produced annually. There is no solid waste produced by evaporation as is the case in other alternatives because the contaminants are removed as a sludge, and the sludge is dewatered using filtration.

Table 5-10. Alternative 4: Treated Water Quality

Constituent	Design Influent Concentrations	Final Effluent Concentrations	Total Decontamination Factor	Total Mass Removed By System (kg/yr)	Toxic Mass Removed By System (kg/yr)
<u>Organic Compounds</u>					
Acetone	(ppb) 70	(ppb) 3.50	20	3.96E+01	
Bisethanolethanedithiol	1	0.05	20	5.66E-01	
Bis(ethylhexyl)phthalate	80	0.80	100	4.72E+01	8.83E+01
2-Butoxyethanol	1	0.05	20	5.66E-01	
2-(2-butoxy ethoxy) ethanol	100	5.00	20	5.66E+01	
Chlorodifluoromethane	20	1.00	20	1.13E+01	
Chloroform	40	2.00	20	2.26E+01	6.68E+02
1,1-Dichloroethane	40	0.40	100	2.36E+01	
Dichlorodifluoromethane	3	0.15	20	1.70E+00	
Ethyl alcohol	3	0.15	20	1.70E+00	
Halogenated hydrocarbons	9	0.45	20	5.10E+00	
Methyl ethyl ketone	5	0.25	20	2.83E+00	
Methylene chloride	4	0.08	50	2.34E+00	
m-Xylene	1	0.01	100	5.90E-01	
o-p-Xylene	1	0.01	100	5.90E-01	
Purgable Organic Halides (POX)	6	0.06	100	3.54E+00	
2-Propanol	4	0.04	100	2.36E+00	
Tetrachloroethylene	10	0.10	100	5.90E+00	4.14E+01
Total Organic Carbon (TOC)	6,000	300.00	20	3.40E+03	
Toluene	2	0.02	100	1.18E+00	4.63E-04
Total Carbon	14,000	700.00	20	7.93E+03	
Total Organic Halides (TOX)	200	10.00	20	1.13E+02	
1,1,1-Trichloroethane	10	0.10	100	5.90E+00	1.79E-03
Trichloroethene	0.4	0.004	100	2.36E-01	1.52E-02
Trichloromonofluoromethane	1	0.05	20	5.66E-01	
Unknown	50	50.00	1	0.00E+00	
Unknown aliphatic HC	3	0.30	10	1.61E+00	
Unknown amide	2	0.20	10	1.07E+00	
Unknown amine	10	1.00	10	5.36E+00	
Unknown aromatic HC	4	0.40	10	2.15E+00	
Unknown fatty acid	30	3.00	10	1.61E+01	
Unknown fatty acid ester	1	0.10	10	5.36E-01	
Unknown PAH	40	4.00	10	2.15E+01	4.29E+04
<u>Inorganic Compounds</u>					
Aluminum	(ppb) 350	(ppb) 3.50	100	2.07E+02	
Ammonia	400	20.00	20	2.26E+02	6.05E-01
Arsenic	10	0.50	20	5.66E+00	1.44E+04
Barium	60	6.00	10	3.22E+01	1.80E-01
Beryllium	30	1.50	20	1.70E+01	1.40E+04
Boron	25	1.25	20	1.42E+01	
Bromide	4	4.00	1	0.00E+00	
Cadmium	10	0.10	100	5.90E-00	3.33E+01
Calcium	30,000	1,500	20	1.70E+04	
Chloride	60,000	60,000	1	0.00E+00	
Chromium	10	0.10	100	5.90E+00	8.20E-01
Copper	80	0.80	100	4.72E+01	2.20E+01

Table 5-10. Alternative 4: Treated Water Quality (cont.)

Constituent	Design Influent Concentrations	Final Effluent Concentrations	Total Decontamination Factor	Total Mass Removed By System	Toxic Mass Removed By System
	(ppb)	(ppb)		(kg/yr)	(kg/yr)
Cyanide	50	50	1	0.00E+00	0.00E+00
Fluoride	200	200	1	0.00E+00	
Iron	600	30	20	3.40E+02	4.30E+01
Lead	60	0.60	100	3.54E+01	6.59E+01
Lithium	30	30	1	0.00E+00	
Magnesium	5,000	250	20	2.83E+03	
Manganese	60	0.60	100	3.54E+01	3.97E+00
Mercury	3	0.03	100	1.77E+00	8.96E+02
Nickel	60	0.60	100	3.54E+01	1.69E+01
Nitrate	6,000	6,000	1	0.00E+00	0.00E+00
Nitrite	400	400	1	0.00E+00	
Phosphate	1,000	1,000	1	0.00E+00	
Potassium	1,000	1,000	1	0.00E+00	
Selenium	6	0.30	20	3.40E+00	2.45E+00
Silicon	3,000	300	10	1.61E+03	
Silver	20	0.20	100	1.18E+01	5.64E+02
Sodium	40,000	40,000	1	0.00E+00	
Strontium	100	10	10	5.36E+01	
Sulfate	30,000	33,333	0.90	-1.99E+03	
Sulfide	100	100	1	0.00E+00	0.00E+00
Tin	100	1.00	100	5.90E+01	
Titanium	7	0.07	100	4.13E+00	
Vanadium	8	0.08	100	4.72E+00	
Zinc	150	1.50	100	8.85E+01	4.51E+00
Uranium	10	0.10	100	5.90E+00	
<b>Total Inorganics</b>	<b>178,943</b>	<b>144,246</b>		<b>2.07E+04</b>	<b>3.01E+04</b>
<b>Radionuclides</b>	<b>(pCi/L)</b>	<b>(pCi/L)</b>		<b>(mCi/yr)</b>	<b>(kg/yr)</b>
Alpha Activity	9	9.00E-01	10	4.83E+00	5.22E-01
Am-241	0.4	4.00E-03	100	2.36E-01	3.12E-02
Beta Activity	40	4.00E+00	10	2.15E+01	4.08E+01
Co-60	1	1.00E-02	100	5.90E-01	6.63E-03
H-3 (tritium)	400	4.00E+02	1	0.00E+00	0.00E+00
Pu-239/240	0.2	2.00E-03	100	1.18E-01	1.32E-02
Radium Total	0.2	1.00E-02	20	1.13E-01	2.12E+00
Ru-106	4	4.00E-02	100	2.36E+00	1.32E-01
Sr-90	1	1.00E-01	10	5.36E-01	1.02E+00
Uranium	8	8.00E-02	100	4.72E+00	8.78E-02
<b>Miscellaneous Parameters</b>	<b>(ppb)</b>	<b>(ppb)</b>		<b>(kg/yr)</b>	<b>(kg/yr)</b>
Alkalinity	60,000	60,000	1	0.00E+00	0.00E+00
Coliform (# per 100 mL)	230	230	1	0.00E+00	
Conductivity-field (µS)	250				
pH-field	9				
Suspended Solids	9,000	90	100	5.31E+03	
Temperature-field (Celsius)	24				
Total Dissolved Solids	120,000	120,000	1	0.00E+00	0.00E+00
Turbidity (NTU)	N/A				

Table 5-11. Alternative 4: Secondary Wastes

Waste Description	Estimated Annual Mass	Estimated Annual Volume
Ion Exchange Resin*	3.08E+03 (kg)	4.27E+00 (m3)
Spent GAC**	1.08E+05 (kg)	6.72E+03 (m3)
Dewatered Metal Sludge***	6.83E+04 (kg)	5.42E+01 (m3)
<b>TOTAL</b>	<b>1.79e+05 (kg)</b>	<b>6.78E+03 (m3)</b>

\*Waste ion exchange resin volume = one-tenth supply of Alternative 1 due to stand-by use  
 \*\*GAC bulk density = 28 lb/cf or 448 kg/m<sup>3</sup>; note that spent GAC may be regenerated  
 \*\*\*Dewatered metal sludge = 35% solids @ 1.74 specific gravity & 65% water @ 1.0 specific gravity

#### 5.4.4 Flexibility

The co-precipitation, clarification, solids dewatering, and water filtration components of Alternative 4 are flexible in their operation. The effectiveness of the co-precipitation process is pH dependent, but the pH can be easily monitored and adjusted. When a suitably high dose of iron is added, greater than 90 percent removal efficiencies can be achieved for a variety of heavy metal ions at variable concentrations. One potential deficiency is that removal of anionic metals has a different pH dependence than does removal of cationic metals: anion removal decreases with increasing pH while cation removal increases. It may be possible to operate at a mid-range pH to achieve satisfactory removal of both types of metals. Alternatively, it may be necessary to use a two-stage system, one operating at high pH, the second at low pH.

The clarifier is purposely sized for maximum loading to achieve high removal of precipitated iron under all conditions. Thus, this unit operation is very flexible by virtue of its oversized capacity.

Because the amount of iron solids produced is relatively small, the filter press is operated intermittently. This step, therefore, has inherent flexibility because it is performed on an as-needed basis.

The sand filters used to polish the effluent from the clarifier are operated similarly to the filters used in Alternatives 1, 2, and 3. As discussed previously, this unit operation is very flexible.

The high flexibility of the GAC adsorption system has been discussed in Section 5.1.4.

#### 5.4.5 Reliability

Alternative 4 is a very reliable treatment system. The co-precipitation, clarifier, filter press, sand filter, and GAC adsorption systems are very reliable, consistent operations.

The co-precipitation process is very reliable, requiring only common, simple process equipment such as corrosion-resistant tanks, pH control equipment, chemical storage tanks, chemical feed pumps, and an aeration system. The overall co-precipitation process has been practiced for many years, but some of the underlying principles have not historically been well understood.

Clarifiers and filter presses have been used in municipal and industrial wastewater treatment for years. A well-designed clarifier performs reliably with unattended operation for years, requiring only routine servicing of some mechanical equipment and perhaps adjustment of doses of flocculent chemicals. Filter presses are fairly involved components, requiring a number of chemical feed pumps and instruments. Nonetheless, filter presses have been automated and can operate virtually unattended.

The reliability of the sand filters and GAC adsorption systems has been discussed previously.

#### 5.4.6 Safety

There are a number of possible safety problems associated with Alternative 4, but these problems are relatively minor, unlikely, or preventable.

Sodium hydroxide is probably the most hazardous chemical used in this process. Contact with sodium hydroxide can cause severe burns and irritation. Iron salt solutions and reagents used with the filter press have lower hazards. Nevertheless, worker contact with these chemicals is minimized by delivering and dispensing chemical supplies directly to the process vessels rather than preparing the solutions on site from solid reagents. The reagent solutions are then pumped directly to the process vessels. Encased piping can be used to prevent leaks. When repair on the piping or pumps is required, the pumps and lines would first be rinsed. The repair workers would then be required to don the appropriate personal protective gear before servicing.

There is the potential for leakage of wastewater throughout the process. Nonetheless, the anticipated wastewater quality (see Table 2-1) indicates a relatively dilute wastewater; most compounds are present at concentrations less than about 50 ppm, and these higher concentrations apply to common ions such as calcium, sodium, chloride, and sulfate. Organic compounds and heavy metals are typically at concentrations lower than 100 ppb. Thus, possible wastewater releases present minimal health threats. Furthermore, a system of collection sumps and drains may be included to capture releases and return the water to process vessels.

Moving parts on the filter press, particularly the plates which open and close forcefully, can cause physical injury. The potential for injury from this piece of equipment

can be prevented by installing light curtains around the press. If the light beam is penetrated by a protruding arm, for example, the filter press will not open or close.

Another potential hazard is the handling of spent GAC and metal sludge. These waste materials may have minor hazards associated with small amounts of organics or heavy metals. Nonetheless, direct handling of the GAC or sludge is not required. The GAC is vacuumed into a truck, and the metal sludge may be pumped or loaded without human contact. Spills will not spread more than a few feet and may be readily cleaned up without leaving significant residuals.

Overall, only minor hazards exist, with proper handling of chemicals and personal protection equipment.

#### 5.4.7 Technical Viability

Filtration, GAC adsorption, clarification, and filter press dewatering are well-established technologies. They have been used extensively in industrial and municipal wastewater treatment applications. Their use on 300 Areas wastewater represents a typical application.

Co-precipitation is not as well established at treating water to low and sub part-per-billion (ppb) metal concentrations. However, it is expected that the 5-10 ppm iron dosage and sludge recirculation will provide sufficient chemicals to treat nearly all metal concentration fluctuations reasonably expected in the Proces Sewer. The co-precipitation process is sensitive to the possible presence of metal chelating compounds such as EDTA. Pilot studies will be necessary to establish final effluent concentrations attainable.

The unit operations utilized in Alternative 4 in general are viable, well-established wastewater treatment technologies.

#### 5.4.8 Capital and Operating Costs

The cost estimate for Alternative 4 is summarized in Table 5-12. The estimate is divided into process equipment costs, costs for other equipment and support, and operation and maintenance (O & M) costs.

The process equipment costs are comprised of the co-precipitation, filtration, GAC adsorption, and stand-by ion exchange unit operations. The total estimated process equipment cost is \$1,200,000. The total estimated capital cost is \$9,500,000 including administration, engineering, permitting, buildings, support equipment, and a contingency. The estimated annual O & M cost is \$3,000,000, about two-thirds of which is operating labor.

For costing purposes it is assumed that the sludge is designated as a Dangerous Waste and requires disposal similar to that of mixed waste. The cost for on-site disposal of solid mixed waste is \$6202/m<sup>3</sup> (\$176/cf). It is assumed that the cost for disposal of Dangerous Waste is similar to that of solid radioactive mixed waste.

Table 5-12. Alternative 4: Cost Estimate

CAPITAL COST

1. Process Equipment

A. Coprecipitation System (2 - 150 gpm)		\$350,000
B. Dual Media Filter (2 - 300 gpm)		\$260,000
C. Plate and Frame Filter Press (20 cu ft)		\$50,000
D. Granular Activated Carbon System (2 - 715 cu ft columns, 300 gpm)		\$212,000
E. Ion Exchange (stand-by) (3 150-cu ft column)		\$300,000
	Cost Factor	Subtotal
		\$1,172,000
2. Auxillary Equipment	0.05	\$58,600
3. Installation	0.10	\$117,200
4. Diversion Basins		\$1,800,000
5. Instrumentation	0.08	\$93,760
6. Building	0.25	\$293,000
7. Facilities	0.15	\$175,800
8. Outside Lines		\$600,000
		Subtotal
		\$4,310,360
9. Engineering	0.27	\$1,163,797
Contract Administration	0.16	\$689,658
Project Management	0.15	\$646,554
		Subtotal
		\$6,810,369
Escalation	0.14	\$953,452
		Subtotal
		\$7,763,820
Contingency	0.23	\$1,785,679
		Project Cost
		\$9,549,499

NOTES:

- 1) Cost data were obtained from WHC-SD-L045H-CDR-001 and vendor information.
- 2) Cost Factors derived from WHC-SD-LO45H-CDR-001.

Table 5-12. Alternative 4: Cost Estimate (cont.)

O & M COST		Annual Cost
1. Materials		
Ferrous Sulfate		\$5,034
Polymer		\$13,146
Sodium Hydroxide		\$97,170
IX Resin		\$30,888
GAC		\$236,500
Sulfuric acid		\$10,700
Filter press reagents and fabric		\$10,000
2. Manpower		
5 shifts@ 4 people/shift		\$2,000,000
3. Secondary Wastes		
GAC	236500 lb	\$236,500
On-site Landfill	4.3 m3	\$8,160
On-site Hazardous Waste Disposal	54 m3	\$336,459
TOTAL ANNUAL O&M COST		\$2,984,556

NOTES:

- 1) Material costs obtained from vendors
- 2) Manpower costs and secondary waste disposal costs obtained from WHC.
- 3) Utility costs were not included because they are a small percentage of the total O&M and they are similar between the alternatives.

The present worth of Alternative 4 is \$47 million and the EUAC is \$3.8 million.

#### 5.4.9 Ease of Maintenance

The ease of maintenance of Alternative 4 is similar to that of Alternative 1 (see Section 5.1.9) with respect to the filtration and GAC adsorption components.

The maintenance requirements of the co-precipitation process are relatively simple. The primary requirements are maintaining process equipment such as pumps and air compressors. Much of the system, including the pH control, chemical dosing, and flow, is controlled automatically. Cleaning is very infrequent (probably no more often than once every five years). Most of the process equipment is easily accessible for maintenance. The filter press requires more servicing and maintenance because of its complexity. Filter cloth must be regularly inspected and cleaned, and periodically replaced. Filter aids and reagents must be re-supplied. Chemical metering pumps must be serviced. Instrumentation must be inspected, recalibrated, and upgraded. These activities are somewhat involved, but not excessively difficult. An operator is usually dedicated to servicing and maintaining this piece of equipment.

The clarifier typically consists of a basin and a scraper arm to direct settled sludge to an exit port. Because of this simple mechanism, maintenance is limited to servicing the motors that drive the scraper. This maintenance consists of motor inspection and periodic servicing.

Operation and maintenance requirements of the sand filter and GAC column have been discussed. One possible difference encountered in Alternative 4 may be the more frequent need to backwash the sand filter, but this difference is not considered major.

### 5.5 ALTERNATIVE 5

#### 5.5.1 Description of Alternative

Alternative 5 consists of coagulation/powdered activated carbon (PAC), clarification, filtration, and stand-by ion exchange. Alternative 5 resembles Alternative 4, except that in Alternative 5 activated carbon adsorption and coagulation are combined in a single unit operation to simultaneously remove organic compounds and heavy metals. Clarification and filtration are used to remove the resulting solids mixture, which is dewatered using a filter press. The ion exchange system is on stand-by to polish the effluent water when metal concentrations are expected to exceed discharge limits.

The operation of Alternative 5 is very similar to that of Alternative 4. One difference is that ferric chloride is added during the coagulation step at a dosage of 30 mg/L. The pH is adjusted to 9.5 to obtain the optimal removal of target compounds. PAC is added at the same time as the coagulant to remove organic compounds but also to assist in the settling of the coagulant floc. A final PAC concentration of 200 mg/L is used. Proof-of-concept

testing has been completed to identify the optimum coagulant, coagulant dosage, and pH (Ebasco 1991b).

The PAC and floc is settled in an inclined plate lamellar or basin clarifier. The effluent from the clarifier is filtered in a sand filter before being discharged. The settled solids are dewatered in a filter press. The solids are then tested and disposed or treated, while the filtrate water is returned to the clarifier.

#### 5.5.2 Treated Water Quality

The estimated composition of treated water from Alternative 5 is presented in Table 5-13. The removal of organic compounds is comparable to the alternatives in which GAC adsorption is used. The removal of heavy metals is similar to that in Alternative 4. There may be a small removal of non-metallic ions, but because ion exchange is not regularly used, this removal is much less than in alternatives in which ion exchange or RO are included.

#### 5.5.3 Secondary Wastes

Secondary waste production from Alternative 5 is quantified in Table 5-14. The predominant waste produced is mixed coagulant/PAC sludge. The backwash water from the sand filters is returned to the clarifier. Also, there is no regeneration of ion exchange resin, so regeneration and backwash wastes produced by the other alternatives are not produced by Alternative 5. However, spent resin is produced because the resin is not regenerated. Assuming a on-line use of one percent, about 4270 liters or 3080 kg (6780 lb) of spent resin are produced annually.

The waste sludge has an assumed solids content of about 40 percent. The estimated annual wet weight is 419,000 kg (922,000 lb). It contains metal precipitate, coagulant, and PAC. It will be tested for hazardous chemical properties. If the tests indicate hazardous properties, the sludge must be treated and/or disposed in a RCRA-permitted facility. If the waste solids are non-hazardous, then the waste solids may be disposed in a conventional solid waste landfill after drainable water is removed or solidified.

#### 5.5.4 Flexibility

The flexibility of Alternative 5 in handling variable loading is good overall, but the coagulation step has some limitations.

The PAC adsorption of organic compounds is very flexible provided an adequate dose of PAC is applied: PAC is capable of adsorbing a wide variety of organic compounds at variable concentrations. As a general rule, organic compounds that have high molecular weights and are less soluble in water adsorb most strongly to activated carbon. Low molecular weight, water-soluble organic compounds require larger amounts of activated carbon.

The coagulation process depends on the composition of the wastewater, the identity of the coagulant, and the dose of coagulant. If the incorrect dose of coagulant is used, the

Table 5-13. Alternative 5: Treated Water Quality

Constituent	Design Influent Concentrations	Final Effluent Concentrations	Total Decontamination Factor	Total Mass Removed By System	Toxic Mass Removed By System
<u>Organic Compounds</u>	(ppb)	(ppb)		(kg/yr)	(kg/yr)
Acetone	70	3.50	20	3.96E+01	
Bisethanolethanedithiol	1	0.05	20	5.66E-01	
Bis(ethylhexyl)phthalate	80	0.80	100	4.72E+01	8.83E+01
2-Butoxyethanol	1	0.05	20	5.66E-01	
2-(2-butoxy ethoxy) ethanol	100	5.00	20	5.66E+01	
Chlorodifluoromethane	20	1.00	20	1.13E+01	
Chloroform	40	2.00	20	2.26E+01	6.68E+02
1,1-Dichlorethane	40	0.40	100	2.36E+01	
Dichlorodifluoromethane	3	0.15	20	1.70E+00	
Ethyl alcohol	3	0.15	20	1.70E+00	
Halogenated hydrocarbons	9	0.45	20	5.10E+00	
Methyl ethyl ketone	5	0.25	20	2.83E+00	
Methylene chloride	4	0.08	50	2.34E+00	
m-Xylene	1	0.01	100	5.90E-01	
o-p-Xylene	1	0.01	100	5.90E-01	
Purgable Organic Halides (POX)	6	0.06	100	3.54E+00	
2-Propanol	4	0.04	100	2.36E+00	
Tetrachloroethylene	10	0.10	100	5.90E+00	4.14E+01
Total Organic Carbon (TOC)	6,000	300.00	20	3.40E+03	
Toluene	2	0.02	100	1.18E+00	4.63E-04
Total Carbon	14,000	700.00	20	7.93E+03	
Total Organic Halides (TOX)	200	10.00	20	1.13E+02	
1,1,1-Trichloroethane	10	0.10	100	5.90E+00	1.79E-03
Trichloroethene	0.4	0.004	100	2.36E-01	1.52E-02
Trichloromonofluoromethane	1	0.05	20	5.66E-01	
Unknown	50	50.00	1	0.00E+00	
Unknown aliphatic HC	3	0.30	10	1.61E+00	
Unknown amide	2	0.20	10	1.07E+00	
Unknown amine	10	1.00	10	5.36E+00	
Unknown aromatic HC	4	0.40	10	2.15E+00	
Unknown fatty acid	30	3.00	10	1.61E+01	
Unknown fatty acid ester	1	0.10	10	5.36E-01	
Unknown PAH	40	4.00	10	2.15E+01	4.29E+04
<u>Inorganic Compounds</u>	(ppb)	(ppb)		(kg/yr)	(kg/yr)
Aluminum	350	3.50	100	2.07E+02	
Ammonia	400	400.00	1	0.00E+00	0.00E+00
Arsenic	10	0.50	20	5.66E+00	1.44E+04
Barium	60	6.00	10	3.22E+01	1.80E-01
Beryllium	30	1.50	20	1.70E+01	1.40E+04
Boron	25	1.25	20	1.42E+01	
Bromide	4	4.00	1	0.00E+00	
Cadmium	10	0.10	100	5.90E+00	3.33E+01
Calcium	30,000	1500.00	20	1.70E+04	
Chloride	60,000	60000.00	1	0.00E+00	
Chromium	10	0.10	100	5.90E+00	8.20E-01
Copper	80	0.80	100	4.72E+01	2.20E+01

Table 5-13. Alternative 5: Treated Water Quality (cont.)

Constituent	Design Influent Concentrations	Final Effluent Concentrations	Total Decontamination Factor	Total Mass Removed By System	Toxic Mass Removed By System
	(ppb)	(ppb)		(kg/yr)	(kg/yr)
Cyanide	50	50.00	1	0.00E+00	0.00E+00
Fluoride	200	200.00	1	0.00E+00	
Iron	600	6.00	100	3.54E+02	8.60E+01
Lead	60	0.60	100	3.54E+01	6.59E+01
Lithium	30	30.00	1	0.00E+00	
Magnesium	5,000	250.00	20	2.83E+03	
Manganese	60	0.60	100	3.54E+01	3.97E+00
Mercury	3	0.03	100	1.77E+00	8.96E+02
Nickel	60	0.60	100	3.54E+01	1.69E+01
Nitrate	6,000	6000.00	1	0.00E+00	0.00E+00
Nitrite	400	400.00	1	0.00E+00	
Phosphate	1,000	1000.00	1	0.00E+00	
Potassium	1,000	1000.00	1	0.00E+00	
Selenium	6	0.30	20	3.40E+00	2.45E+00
Silicon	3,000	300.00	10	1.61E+03	
Silver	20	0.20	100	1.18E+01	5.64E+02
Sodium	40,000	40000.00	1	0.00E+00	
Strontium	100	10.00	10	5.36E+01	
Sulfate	30,000	30000.00	1	0.00E+00	
Sulfide	100	100.00	1	0.00E+00	0.00E+00
Tin	100	1.00	100	5.90E+01	
Titanium	7	0.07	100	4.13E+00	
Vanadium	8	0.08	100	4.72E+00	
Zinc	150	1.50	100	8.85E+01	4.51E+00
Uranium	10	0.10	100	5.90E+00	
<b>Total Inorganics</b>	<b>178,943</b>	<b>141,269</b>		<b>2.25E+04</b>	<b>3.01E+04</b>
<b>Radionuclides</b>	<b>(pCi/L)</b>	<b>(pCi/L)</b>		<b>(mCi/yr)</b>	<b>(kg/yr)</b>
Alpha Activity	9.00E+00	1.80E+00	10	4.29E+00	5.22E-01
Am-241	4.00E-01	4.00E-02	100	2.15E-01	3.12E-02
Beta Activity	4.00E+01	8.00E+00	10	1.91E+01	4.08E+01
Co-60	1.00E+00	1.00E-01	100	5.36E-01	6.63E-03
H-3 (tritium)	4.00E+02	4.00E+02	1	0.00E+00	0.00E+00
Pu-239/240	2.00E-01	2.00E-02	100	1.07E-01	1.32E-02
Radium Total	2.00E-01	4.00E-02	20	9.54E-02	2.12E+00
Ru-106	4.00E+00	4.00E-01	100	2.15E+00	1.32E-01
Sr-90	1.00E+00	2.00E-01	10	4.77E-01	1.02E+00
Uranium	8.00E+00	8.00E-01	100	4.29E+00	8.78E-02
<b>Miscellaneous Parameters</b>	<b>(ppb)</b>	<b>(ppb)</b>		<b>(kg/yr)</b>	<b>(kg/yr)</b>
Alkalinity	60,000	60,000	1	0.00E+00	0.00E+00
Coliform (# per 100 mL)	230	230	1	0.00E+00	
Conductivity-field (µS)	250				
pH-field	9				
Suspended Solids	9,000	90	100	5.31E+03	
Temperature-field (Celsius)	24				
Total Dissolved Solids	120,000	120,000	1	0.00E+00	0.00E+00
Turbidity (NTU)	N/A				

Table 5-14. Alternative 5: Secondary Wastes

Waste Description	Estimated Annual Mass	Estimated Annual Volume
Ion Exchange Resin*	3.08E+03 (kg)	4.27E+00 (m3)
Dewatered Sludge**	4.19E+05 (kg)	3.22E+02 (m3)
<b>TOTAL</b>	<b>4.22E+05 (kg)</b>	<b>3.27E+02 (m3)</b>

\* Waste ion exchange resin volume = one-tenth supply of alternative 1 due to stand-by use

\*\* Dewatered sludge = 40% solids @ 1.74 specific gravity & 60% water @ 1.0 specific gravity and includes spent PAC

resulting floc may not settle well and it may not adequately remove heavy metals. Additionally, the process tends to remove anions less effectively than cations. These potential shortcomings are usually overcome by adding a sufficiently high dose of coagulant to ensure high removal.

The high flexibility of the sand filters, filter press, and clarifier was discussed in Section 5.4.4 to which the reader is referred.

#### 5.5.5 Reliability

Because Alternative 5 consists of technically simple unit operations, it is expected to be very reliable. The coagulation/PAC step consists of feeding coagulant and PAC from holding tanks and contacting them with the wastewater. The mixture is then allowed to settle, and the settled solids are removed and dewatered. Coagulation is a common application in the wastewater treatment industry. It can operate unattended for days if properly designed. There are not many moving parts, and those present, including pumps and slow-speed mixers, are very reliable. Thus, mechanical failure is infrequent.

The reliability of the clarifier, filter press, and sand filter was discussed in Section 5.4.5.

#### 5.5.6 Safety

Alternative 5 is a very safe process. Few strong chemicals are used, the potential for leaks and fugitive emissions is small, and, if leaks were to occur, the wastewater is sufficiently dilute that leaks would pose little significant health risk.

Chemicals used in the treatment train include the coagulant, PAC, limited amounts of acid and base for pH adjustment, and perhaps filter aids and polyelectrolytes to assist in the filter pressing and solids settling, respectively. However, these chemicals do not present

serious health threats because virtually no direct contact with the chemical occurs and simple precautions minimize potential health impacts. For example, PAC may be manually handled but respiration of fine particles must be prevented. Therefore, workers handling the PAC must wear respirators or dust masks. Acids and bases are delivered and dispensed into closed containers and are withdrawn by pumps, thereby minimizing worker contact.

Possible wastewater releases present minimal health threats. Furthermore, collection sumps and drains are included to capture releases and return the water to process vessels.

Because the wastewater may be processed in open tanks, such as the coagulant contact tank, there is the potential for releases of volatile organic compounds (VOCs). Two considerations indicate that these potential releases should be negligible. The first consideration is that the concentration of purgeable organic halides (POX), which gives a measure of releases of organic compounds, is estimated to be only 6 ppb. This low concentration suggests minimal releases to the atmosphere. The second consideration is that possible volatile releases can be controlled by installing a ventilation system to remove the low levels of VOCs released.

The safety of the other process components was discussed in Section 5.4.6.

#### 5.5.7 Technical Viability

The technical viability of most of the components of Alternative 5 is very good. The one component which has not been thoroughly tested is the combined coagulation/PAC operation.

As discussed in Section 5.4.7, the clarifier, sand filter, filter press, and ion exchange systems are common technologies and their use in this process represents a typical application. These technologies will perform their intended functions.

Coagulation and PAC have been successfully used to remove heavy metals and organic compounds, respectively, in separate applications. While their combined use in a single operation is a reasonable extension of the two technologies, the combination has not been demonstrated commercially. Proof-of-concept testing has been completed which has shown that coagulation in combination with PAC can remove in excess of 80% of the metals of concern. Additional testing will be required to firmly establish treated water concentrations which can routinely be obtained.

The unit operations utilized in Alternative 5 are viable, well-established wastewater treatment technologies. The major uncertainty is the final metal concentrations which can consistently be obtained using the coagulation/PAC combination.

#### 5.5.8 Cost

The cost estimate for Alternative 5 is summarized in Table 5-15. The estimate is divided into process equipment costs, costs for other equipment and support, and operation and maintenance (O & M) costs.

Table 5-15. Alternative 5: Cost Estimate

CAPITAL COST

1. Process Equipment			
A. Flocculation/Clarification System (300 gpm)			\$350,000
B. Dual Media Filter (2 - 300 gpm)			\$260,000
C. Plate and Frame Filter Press (20 cu ft)			\$50,000
D. Ion Exchange (stand-by)			\$300,000
(3 150-cu ft columns)			
	Cost	Subtotal	<u>\$960,000</u>
	Factor		
2. Auxillary Equipment	0.05		\$48,000
3. Installation	0.10		\$96,000
4. Diversion Basins			\$1,800,000
5. Instrumentation	0.08		\$76,800
6. Building	0.25		\$240,000
7. Facilities	0.15		\$144,000
8. Outside Lines			\$600,000
		Subtotal	<u>\$3,964,800</u>
9. Engineering	0.27		\$1,070,496
Contract Administration	0.16		\$634,368
Project Management	0.15		\$594,720
		Subtotal	<u>\$6,264,384</u>
Escalation	0.14		\$877,014
		Subtotal	<u>\$7,141,398</u>
Contingency	0.23		\$1,642,521
		Project Cost	<u>\$8,783,919</u>

NOTES:

- 1) Cost data were obtained from WHC-SD-L045-CDR-001 and vendor info.
- 2) Cost Factors derived from WHC-SD-LO45H-CDR-001.

Table 5-15. Alternative 5: Cost Estimate (cont.)

O & M COST		Annual Cost
1. Materials		
PAC		\$236,500
Coagulant		\$6,000
Polymer		\$13,146
Sodium Hydroxide		\$97,170
IX Resin		\$30,888
Sulfuric acid		\$10,700
2. Manpower		
5 shifts@ 4 people/shift		\$2,000,000
3. Secondary Wastes		
On-site Landfill	4.27 m3	\$8,160
On-site Hazardous Waste Disposal	322 m3	\$1,997,044
TOTAL ANNUAL O&M COST		\$4,399,608

NOTES:

- 1) Material costs obtained from vendors
- 2) Manpower costs and secondary waste disposal costs obtained from WHC.
- 3) Utility costs were not included because they are a small percentage of the total O&M and they are similar between the alternatives.

The process equipment costs are comprised of flocculation/clarification, filtration, and ion exchange unit operations. The total estimated process equipment cost is \$1,960,000. The total estimated capital cost is \$8,800,000 including administration, engineering, permitting, buildings, support equipment, and a contingency. The estimated annual O & M cost is \$4,400,000, almost one-half of which is for secondary waste disposal.

The present worth of Alternative 2 is \$63 million with an EUAC of \$5.1 million.

#### **5.5.9 Ease of Maintenance**

Maintenance requirements for Alternative 5 are essentially the same as for Alternative 4 as discussed in Section 5.4.9, to which the reader is referred. Essentially, service requirements for most of the components requires replenishing the supplies of reagents and performing routine inspection and maintenance. The filter press is somewhat more involved, but many of its maintenance requirements are automated.

## 6.0 EVALUATION OF THE CANDIDATE TREATMENT SYSTEMS

Alternative 4, consisting of chemical coprecipitation, clarification, filtration, and granular activated carbon adsorption, was determined to be the Best Available Technology, economically achievable, for treatment of the 300 Area Process Sewer wastewater.

The five proposed alternatives described in Section 5.0 are evaluated in this chapter. The categories discussed previously (secondary waste production, technical feasibility, safety, etc.) as well as cost effectiveness form the basis of comparison. Tables 6-1 and 6-2 summarize the cost data and secondary waste data, respectively, developed in Section 5.0. It should be remembered when considering the costs listed in Table 6-1, that they are rough order-of-magnitude (ROM) and are for comparison purposes. While attempts were made to accurately cost the major items for each alternative, capital costs were based on scaling factors applied to process equipment.

Table 6-1. Costs of L-045H Treatment Alternatives

Alternative	Cost			
	Capital	Annual O&M	Present Worth	EUAC
1	\$9,200,000	\$12,100,000	\$159,000,000	\$12,800,000
2	\$11,600,000	\$4,600,000	\$69,000,000	\$5,600,000
3	\$14,400,000	\$4,500,000	\$70,000,000	\$5,600,000
4	\$9,500,000	\$3,000,000	\$47,000,000	\$3,800,000
5	\$8,800,000	\$4,400,000	\$63,000,000	\$5,100,000

An additional final point of comparison between the alternatives is economic achievability. Economic achievability is determined using the cost-effectiveness method as specified in the WHC BAT guidance document (WHC 1988). This method uses the toxic mass and EUAC calculated in Section 5.0 for each alternative. The alternatives are ranked based on increasing EUAC and the incremental cost and incremental toxic removal calculated. The cost/benefit of each alternative is then obtained by ratioing the cost and toxic removal. An initial upper threshold has been set at \$200/kg. Table 6-3 shows the cost effectiveness of the five alternatives. As seen, the additional toxicity removal obtained by Alternatives 1,2,3, and 5 are found to be excessively costly compared to Alternative 4.

Table 6-2. Secondary Waste Generation of L-045H Treatment Alternatives

Alternative	Toxic Equivalents Removed  (tonnes/yr)	Secondary Waste Mass			
		Landfill  (tonnes/yr)	LDR  (tonnes/yr)	GAC  (tonnes/yr)	Total  (tonnes/yr)
1	75.4	30.8	2600	108	2739
2	1.4	1.1	560	108	669
3	1.3	1.1	560	0	561
4	73.8	3.1	68.3	108	179
5	73.8	3.1	419	0	422

Table 6-3. Cost Effectiveness of L-045H Treatment Alternatives

Alternative	"A"	"B"	A/B
	Incremental EUAC	Incremental Toxic Mass  (kg)	
4	\$0	0	-
5	\$1,300,000	0	-
2	\$1,800,000	5600	\$321
3	\$1,800,000	5500	\$327
1	\$9,000,000	1600	\$5625

Note: Increments shown in "A" and "B" reflect the differences in EUAC and toxic mass between the levels of Alternative 4, which exhibits the lowest EUAC and the lowest toxic mass removed, and the other alternatives.

Table 6-4 summarizes the evaluation. In Table 6-4 each alternative is scored for each of nine criteria, which are weighted according to their perceived relative importance. The total score shown is the sum of the products of the score and weighting for each criterion.

Table 6-4. Evaluation of L-045H Treatment Alternatives

Criterion	Weight	Alternative 1		Alternative 2		Alternative 3		Alternative 4		Alternative 5	
		Raw	Score								
Treated Water Quality	10	3	30	3	30	3	30	2	20	2	20
Secondary Wastes	9	1	9	2	18	2	18	3	27	2	18
Flexibility	7	3	21	3	21	3	21	2	14	2	14
Reliability	9	3	27	2	18	2	18	3	27	3	27
Safety	10	3	30	3	30	3	30	3	30	3	30
Technical Viability	10	3	30	3	30	2	20	3	30	3	30
Project Cost	5	1	5	2	10	2	10	3	15	2	10
Ease of Maintenance	6	2	12	2	12	2	12	3	18	3	18
Cost Effectiveness	5	1	5	1	5	1	5	3	15	1	5
<b>Total Score</b>		<b>169</b>		<b>174</b>		<b>164</b>		<b>196</b>		<b>172</b>	

Notes: Rating 3 = High  
 Rating 2 = Medium  
 Rating 1 = Low  
 All ratings are relative to the technology choices as shown.

The weighting of the selected criteria is based on a scale of 1 (low) to 10 (high). The rationale for the weighting factors follows. Treated water quality, safety, and technical viability are given weights of 10. These criteria are considered to be of major importance to the success of the L-045H treatment facility. In effect, the treatment system must be able to treat the wastewater to a high quality without endangering plant personnel, the public, or the environment. Secondary waste production is given a weight of 9. While not critical to success of the treatment system, it is very important that secondary waste production be minimized to the extent possible. Reliability, as measured by system operating efficiency (on-stream time), is a combination of process reliability and equipment reliability. Process reliability reflects the ability of the technology to treat the wastewater without undue operating complexity. Equipment reliability reflects the potential for equipment failures taking into account basic process parameters such as the presence of extreme temperature or pressure conditions, the reliance on rotating equipment, the type of construction materials, and the degree of design experience presented by the technology vendor. A weighting factor of 9 reflects the crucial nature of being able to continually treat the Process Sewer wastewater.

Flexibility is assigned a weight of 7 because it is a highly desirable feature, but not critical to the success of the system. In other words, lack of process flexibility to feedstream fluctuations can be overcome by additional operating personnel, instrumentation, and operator care in controlling process variables. Ease of maintenance, project cost, and cost effectiveness are given weights of 5. Relative ease of maintenance is important to lasting operating and worker safety. Overall cost and cost effectiveness are significant points of comparison only after the other objectives have been satisfied.

## 6.1 EVALUATION OF ALTERNATIVE 1

Alternative 1 is expected to perform well in most categories. Overall, the Alternative 1 process relies on filtration to remove suspended solids, GAC to remove organic compounds, and ion exchange to remove dissolved ions, including heavy metals. MVR evaporation concentrates secondary wastewater.

The quality of treated water from Alternative 1 is very good. The organic compounds are predominantly removed by the GAC, reducing most organics by about 95 percent. The inorganic compounds are removed to less than 1 percent of their original concentration by ion exchange. In comparison to the other alternatives this alternative is given a high rating for treated water quality.

Secondary wastes produced annually by Alternative 1 include concentrated wastewater (2,260,000 liters annually), spent GAC (108,000 kg), and ion exchange resin (30,800 kg). The amount of concentrated wastewater is five times that of other alternatives in which RO precedes ion exchange. The mass of spent GAC produced by Alternative 1 is essentially the same as in Alternatives 2 and 4 because the GAC is the major unit operation responsible for removal of organics in all these alternatives. The amount of ion exchange resin produced is higher than in other alternatives because there is no operation such as RO to reduce the loading to the ion exchange system. A low score is given for secondary waste production.

The flexibility of this alternative is very good. The performance of the filter and ion exchange is somewhat susceptible to fluctuating loading, but is compensated for by over-sizing the filter and operating ion exchange in series. GAC is very good in handling variable loading. A high flexibility rating is given.

Alternative 1 is a highly reliable system, and is therefore given a high rating. All of the primary steps in this alternative, filtration, GAC adsorption, and ion exchange are passive and require little attention other than monitoring. The evaporator is somewhat less reliable due to the large pumps and compressors required by MVR. A high rating is given.

Alternative 1 is considered a very safe process. Fugitive emissions are unlikely. Handling of the large quantities of hazardous secondary waste represents a small, but manageable, safety concern. The evaporator has some potential to cause injury resulting from possible releases of high temperature water or steam, but this risk can be reduced with proper design and operation.

The technical viability of Alternative 1 is good. Each step is a well-established technology that has been fully demonstrated on similar wastewater constituents.

The cost of Alternative 1, as measured by the present worth or the equivalent uniform annualized cost (EUAC), is considerably higher than the cost of the other alternatives. The present worth is estimated to be \$276 million, and the EUAC is estimated to be \$2.2 million. Alternative 1 has a lower capital cost than Alternatives 2, 3, and 4, but has a much higher O&M cost. A low rating is given.

Alternative 1 is moderately easy to maintain. The filters are simply backwashed, the GAC is replaced with a hydraulic system that requires very little personnel handling, and the ion exchange resin is easy to regenerate. The MVR evaporator requires regular maintenance to prevent excessive wear, scale build-up, and corrosion. Because the maintenance requirements are significant, but not unwieldy, a moderate rating is given.

Alternative 1 has a very high incremental cost for removal of toxic equivalents. By all measures this is excessive and is given a low rating.

The overall score of Alternative 1 is 169, ranking it fourth among the five alternatives.

## 6.2 EVALUATION OF ALTERNATIVE 2

Alternative 2, in which an RO system has been added in between the GAC adsorption and ion exchange unit operations, performs very well in treating the influent water. The removal of organic compounds is greater than in Alternative 1 and the removal of the inorganics is slightly improved. A high score is given.

Significantly less secondary waste is produced by Alternative 2 than Alternative 1. This reduction is due to the addition of the RO system, which greatly reduces the frequency of ion exchange regeneration and consequently, the amount of regeneration chemicals required. The amount of other secondary wastes is about the same, except for the small

amount of used RO membranes produced by Alternative 2. Alternative 2 receives a moderate rating for secondary waste production.

The flexibility of Alternative 2 is good, comparable to Alternative 1 except for the RO system. The RO membranes are susceptible to fouling with fluctuating loading, but the treated water quality will not be affected significantly. Sufficient RO equipment oversizing is required to compensate for fouling. This alternative is given a high rating for flexibility.

The reliability of Alternative 2 is very good. As stated in the evaluation of Alternative 1 the reliability of filtration, GAC, and ion exchange is very good. The RO and evaporator systems however are less reliable due to the high pressures and temperatures required, therefore, Alternative 2 is given only a moderate score.

The safety of Alternative 2 is comparable to Alternative 1. One difference is that RO membranes will have to be replaced occasionally, requiring handling, but the safety is still considered high.

The technical viability of Alternative 2 is considered to be good overall. The RO system provides a second stage of organics removal to compensate for GAC's inability to remove certain organics. It also improves the performance of the ion exchange system. A high rating is given.

The present worth of Alternative 2 is estimated to be \$110 million and the EUAC is estimated to be \$8.9 million. The capital cost of Alternative 2, about \$12 million, is greater than the \$9.2 million of Alternative 1, but the O&M cost of \$7.9 million is less than the \$21.5 million of Alternative 1. A moderate rating is given.

The ease of maintenance of Alternative 2 is similar to that of Alternative 1, although Alternative 2 includes RO membrane replacement, which is not a difficult or frequent task. A moderate rating is given.

The cost effectiveness of Alternative 2 is considered poor based on an incremental cost of \$875 per toxic equivalent kilogram. A low rating is given.

The overall score of Alternative 2 is 174, ranking it second among the five alternatives.

### 6.3 EVALUATION OF ALTERNATIVE 3

Alternative 3 is similar to Alternative 2, with UV/Oxidation replacing GAC. The overall performance of Alternative 3 is similar to that of the previous two alternatives except the secondary waste production and reliability are lower.

The treated water quality is very good in this alternative; most organic compounds are removed by 90 to 99 percent and inorganics are removed by greater than 99 percent. A high score is given.

Overall secondary waste production is reduced slightly compared to Alternative 2 because there is no spent GAC produced in this alternative. Spent GAC or PAC represents a significant secondary waste stream in all the other alternatives. Burned-out UV lamps produced by Alternative 3 are not produced by the other alternatives, but represent a small waste stream. A moderate rating is given.

The flexibility of Alternative 3 is scored as high. The performance of the UV/oxidation component is somewhat susceptible to fluctuating loading, but is compensated for by over-sizing. The RO membranes can also be affected by fouling, but this potential problem can also be corrected by over-sizing.

Alternative 3 should be fairly reliable with good design. The filtration and ion exchange are passive systems which operate near ambient conditions. UV oxidation should prove reliable as long as fouling of the quartz tubes doesn't become excessive. The RO and evaporator systems operate at elevated pressures and temperatures and utilize large pumps and compressors. The system reliability is considered to be moderate.

The safety of Alternative 3 is also high. Potential safety hazards are small and manageable.

The technical viability of Alternative 3 is moderate. All of the processes in this alternative are established technologies. However, the UV/oxidation system must be tested for efficacy.

Alternative 3 has a present worth of \$111 million or an EUAC of \$8.9 million. These costs are very similar to Alternative 2. The capital cost of \$14.4 million is the highest of the alternatives and the annual O&M cost of \$7.8 million is lower than Alternative 1 but similar to Alternative 2. A moderate rating is given.

Alternative 3 is relatively easy to maintain, requiring replacement of UV lamps, RO membranes, and ion exchange resin. Regular cleaning and servicing of the components is also needed. The score for this criterion is moderate.

The cost effectiveness of Alternative 3 is similar to that of Alternative 2. Similarly a low rating is given.

The overall score is 164, ranking it fifth among the five alternatives.

#### 6.4 EVALUATION OF ALTERNATIVE 4

Alternative 4 differs significantly from the first three alternatives. Instead of removing dissolved ions using unit operations such as RO and ion exchange, co-precipitation is used to remove mainly heavy metal ions. An ion exchange system is available on stand-by, but only for use when effluent metal concentrations are expected to exceed discharge limits due to a process upset. Also, there is no need for an evaporator. Solids from the co-precipitation process are settled, then dewatered in a filter press.

The removal of organic compounds by Alternative 4 is comparable to that of Alternatives 1 and 2 because GAC adsorption is used in all three options. The removal of heavy metals is also comparable. However, Alternative 4 is less effective for removal of other inorganics. Therefore, a moderate rating is given for treated water quality.

The secondary waste produced by Alternative 4 is small compared to the other alternatives roughly one-third the mass from Alternatives 2 and 3. The amount of spent GAC is comparable to the amounts produced by Alternatives 1 and 2. However, the metal sludge produced by this process, estimated to be 68,000 kg annually, is much lower than the MVR wastes primarily because sodium, chloride, and sulfate ions are not removed by Alternative 4. These three ions make-up more than 70% of the influent dissolved solids. A high rating is given.

The flexibility of Alternative 4 is good. Co-precipitation can be adjusted to changes in flow, and the clarifier is deliberately oversized to accommodate any changes. As in the UV/oxidation system, fluctuations of influent concentration can be compensated for by increasing the chemical dosage. As discussed earlier, the filters are highly flexible. The filter press can handle variable production by storing the metal sludge prior to processing. A moderate rating is given.

Alternative 4 is a very reliable system. The coprecipitation, clarifier, filter press, sand filter, and GAC adsorption systems are very reliable, consistent operations. The system is very simple and should operate unattended. All equipment is automated and utilizes gravity flow as much as possible. This alternative is given a high rating.

There are some possible safety hazards associated with Alternative 4 but these problems are relatively small and preventable. Dealing with harsh chemicals such as sodium hydroxide can cause severe burns, but personnel can take proper personal protective precautions. There is also the possibility of leakage of wastewater, but contaminant concentrations are low enough not to cause any harm. The score for safety is high.

The technical viability of filtration, GAC adsorption, clarification, and filter press dewatering is very good. The effectiveness of co-precipitation is not as well-established at the low metal concentrations expected in the influent. Further treatability studies will be required. The technical viability for Alternative 4 is rated as high.

The estimated present worth of Alternative 4 is \$50 million and the estimated EUAC is \$4 million. These costs are less than the costs of Alternatives 1, 2, 3, and 5. A high rating is given.

The maintenance of the co-precipitation, sand filters, filter press, and ion exchange systems are simple. The filters are backwashed, the GAC is replaced with a hydraulic system that requires very little personnel handling, and the ion exchange resin is easy to replace when it is used. Alternative 4 is given a high rating for ease of maintenance.

Alternative 4 is the baseline alternative for determination of incremental cost effectiveness. It is considered to be highly cost effective.

The total score for Alternative 4 is 196, ranking it first among the five alternatives.

## 6.5 EVALUATION OF ALTERNATIVE 5

Alternative 5 is similar to Alternative 4, differing in the use of combined coagulation/PAC adsorption instead of co-precipitation. Filtration, stand-by ion exchange, and filter press dewatering are common to both alternatives.

The removal of organic compounds by Alternative 5 is comparable to that of alternatives in which GAC is used. As was the case with Alternative 4, Alternative 5 removes mainly heavy metals but not other dissolved inorganics. Therefore, a moderate rating is given for treated water quality.

The secondary waste produced by Alternative 5 is larger than by Alternative 4 due to higher coagulant dosage requirements. Instead of spent GAC which can be regenerated, PAC is mixed with the coagulant, rendering it unsuitable for regeneration. A moderate rating is given.

The flexibility of Alternative 5 is good. Coagulant dosage and PAC dosage must be adjusted to accommodate changes in flow and loading. The clarifier is deliberately oversized to handle higher loading. As discussed earlier the filters are highly flexible. The filter press can handle variable production by storing the metal sludge prior to processing. A moderate rating is given.

Alternative 5 is a very reliable system. The clarifier, filter press, sand filter, and GAC adsorption systems are very reliable, consistent operations. This alternative is rated high.

There are some possible safety hazards associated with Alternative 5 but these problems are relatively small and preventable. Dealing with harsh chemicals such as sodium hydroxide can cause severe burns, but personnel can take proper personal protective precautions. There is also the possibility of leakage of wastewater, but the contaminant concentrations are low enough not to cause any harm. The score for safety is high.

The technical viability of filtration, clarification, and filter press dewatering is very good. The combined coagulation/PAC adsorption has only been tested as proof-of-concept for this wastewater. Additional treatability tests must be conducted prior to using this technology. The technical viability for Alternative 5 is rated as high.

The estimated present worth of Alternative 5 is \$92 million and the estimated EUAC is \$7.4 million. These costs are similar to the costs of Alternatives 2 and 3. A moderate rating is given.

The ease of maintenance of Alternative 5 is essentially identical to Alternative 4. A high rating is given.

The cost effectiveness for Alternative 5 is unique because similar toxic removals were assumed but costs are higher than Alternative 4 due to additional secondary waste generation. A low rating is given.

The total score for Alternative 5 is 172, ranking it third among the five alternatives.

## 6.6 CONCLUSIONS

Alternative 4 is identified as the preferred alternative in Table 6-4. Several qualifications however are in order. Alternatives 4 and 5 are equivalent except for the means of introduction of iron solution and the application of activated carbon. The major difference is the final deposition of the carbon. Additional treatability studies for Alternative 4 should address the potential use of PAC addition. Alternative 2 which was ranked second, should produce a higher quality water for discharge than Alternative 4. This higher level of treatment however is obtained with greatly increased complexity, reduced system reliability, and higher costs. Alternative 4 has an estimated 20% lower capital cost and 60% lower O&M costs, than Alternative 2. Lower secondary waste volumes are also produced by Alternative 4. The smaller waste volumes account for a majority of the O&M cost difference.

Additional discussion regarding the secondary waste volumes is warranted. The wastewater influent concentrations (see Table 2-1) show that sodium and chloride ions make up greater than 50% of the dissolved solids mass. The major difference between Alternatives 2 and 4 is the removal of these ions; Alternative 2 removes them, while Alternative 4 does not. A major source of sodium and chloride is regeneration of the Building 384 Powerhouse water softener. Should this source be eliminated, the secondary waste volume estimates for Alternative 2 would be halved.

Another factor affecting the waste volumes, is the degree to which the waste is assumed to be dewatered. It is assumed, in Alternative 2, that the RO rejects are dewatered to 20 weight percent dissolved solids in an evaporator. In Alternative 4, it is assumed that the secondary waste is dewatered to 35 weight percent solids in a filter press. The basis for these assumptions was provided in section 5.0.

Based on these considerations, the Best Available Technology, economically achievable, for treatment of the 300 Area Process Sewer wastewater is the application of source controls and wastewater treatment utilizing the Alternative 4 process concept.

The cost effectiveness for Alternative 5 is unique because similar toxic removals were assumed but costs are higher than Alternative 4 due to additional secondary waste generation. A low rating is given.

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Based on these considerations, the Best Available Technology, economically achievable, for treatment of the 300 Area Process Sewer wastewater is the application of source controls and wastewater treatment utilizing the Alternative 4 process concept.

## 7.0 SELECTED TREATMENT ALTERNATIVE

### 7.1 INTRODUCTION

Alternative 4 has been selected as the Best Available Technology for treatment of the 300 Area Process Sewer wastewater and is discussed in detail in this chapter. The design parameters are covered along with the ability of this alternative to meet its treatment targets. Personnel training information for the equipment is also included. The uncertainties surrounding the treatment process are explored and SEPA/NEPA compliance is discussed.

### 7.2 DESIGN PARAMETERS

The overall treatment process for the L-045H waste stream consists of eight steps. The first step of the treatment process is an equalization tank. This tank equalizes the flow of the entering waste stream, providing a more consistent composition and flow rate to the following treatment equipment. The tank has a 6 meter (20 ft) diameter and 7 meter (23 ft) height with a volume of 190,000 liters (50,000 gallons). The tank is constructed of corrosion-resistant materials and is equipped with a mixer, overflow, and level-controlled feed pump. The 190,000 liter volume provides an average hydraulic retention time of over 2 hours.

After flow equalization, the wastewater is pumped to a co-precipitation reactor. Two 570 lpm (150 gpm) reactors are provided to increase system flexibility. The reactors are constructed of corrosion-resistant materials and are equipped with variable speed mixers, chemical addition systems, and pH control units.

Following the reactors, the wastewater slurry is gravity fed to a 1,135 lpm (300 gpm) inclined-plate clarifier. The clarifier is manufactured of corrosion-resistant materials and includes an integral flocculation unit. The clarifier/flocculation unit includes a pneumatic sludge transfer pump and potentially a sludge recirculation pump piped back to the reactors.

The fourth treatment step is filtration. The clarified effluent is passed through a sand filter to remove residual solids. Two sand filters will be present, one in operation and the second on standby. The sand filter will be sized to remove particles larger than about 2 micrometers. The filter vessels will have a 1.5 meter (5 ft) diameter and a 2 m<sup>2</sup> (21 ft<sup>2</sup>) effective filtration area. The filters will include a 30 hp feed pump and automatic backwash systems triggered by measured pressure drops across the filter. The backwashed water will be returned to the clarifier.

The fifth step in the treatment process is granular activated carbon (GAC) adsorption. This process requires a minimum of 15 minutes residence time of the waste stream within the GAC vessel. Because of this contact time requirement, the GAC columns are 3 meters (10 feet) in diameter and 3 meters (10 feet) tall and are packed with 9000 kg (20,000 lbs) of GAC. Two such vessels are provided and operated in series. Assuming that the required carbon dosage will be 1 kg per 8000 liters, one column will require carbon replacement approximately each month. There will be ancillary equipment with the GAC columns to facilitate carbon replacement.

The sixth treatment step is ion exchange which is maintained in stand-by condition for treatment of process upsets. Three mixed-bed ion exchange columns are provided. When in operation, two columns are used in series. Each ion exchange column is 1.2 meters (4 feet) in diameter, 3.7 meters (12 feet) high, and holds 4.27 cubic meters (151 cf) of ion exchange resin. The system includes ancillary equipment to facilitate replacement of the spent resin. No facilities are provided for resin regeneration.

The settled solids collected from the bottom of the clarifier are pumped to a sludge holding tank, the seventh step in the treatment system. The sludge tank is a corrosion-resistant 15,000 liter (4000 gallon) vessel 2.4 meters (8 ft) in diameter and 4.6 meters (15 ft) in height.

The eighth and final step in the treatment system is a Plate-and-Frame filter press. This filter is used to dewater the sludge pumped from the holding tank. The filter has a 0.6 m<sup>3</sup> (20 ft<sup>3</sup>) capacity and includes a pneumatic feed pump and sludge hopper.

### 7.3 ABILITY TO MEET TREATMENT TARGETS

The treatment goal of the L-045H wastewater treatment facility is to remove organics and inorganics to levels meeting the various discharge criteria. It is impossible to determine exactly what treatment levels can be achieved without the benefit of full treatability test results. Therefore, the values used in this report are based upon proof-of-concept treatability tests, and assistance from vendors and water treatment specialists who have analyzed the influent contaminants.

The co-precipitation system is an established, standard treatment method for removal of metals from wastewater. The decontamination factors for heavy metals are estimated to be 100, while those for the light metals are 20. No decontamination is assumed for the alkali metals and most anions. Further treatability studies will be required to establish actual removals of anions. This process is effective in removing the target metals.

The sandfilter is not intended to remove a substantial amount of contaminants. Its primary function is to remove suspended solids carried over from the clarifier.

The GAC is very effective in removing a broad spectrum of organics from the waste stream. The decontamination factors for the organics are estimated to be 20 - 50. This step has the ability to meet the desired level of organic removal.

The last step is stand-by ion exchange. This process has negligible effect on organic removal; therefore, all decontamination factors are 1. However, ion exchange is excellent in removing the inorganics and the radionuclides. In general, the decontamination factors are estimated to range from 1,000 to 10,000. These decontamination factors however, were not applied because ion exchange is assumed to operate only during process upsets.

The decontamination factors projected for the overall treatment process indicate that Alternative 4, in most cases, can successfully remove a majority of the contaminants from

the waste stream to effluent levels near or below the most restrictive targets identified in Table 3-1.

#### 7.4 PERSONNEL TRAINING REQUIREMENTS

One important consideration in the implementation of the L-045H wastewater treatment facility is the training of personnel to operate the treatment system. There are requirements for personnel to maintain the building, monitor and control the instrumentation, and operate and service the equipment. The following discussion focuses on the personnel training requirements needed to correctly operate and maintain the process equipment included in Alternative 4.

The process equipment includes holding tanks, filters, precipitation vessels, a clarifier, a GAC adsorption system, and stand-by ion exchange. Most of these components require little maintenance or specialized training.

The storage tanks require minimal maintenance. Occasionally, a structural engineer may be called upon to inspect the structural integrity of the tank. Because of the infrequent need for this service, training of on-site personnel for this task is unnecessary.

The co-precipitation system can be designed for fully automated operation requiring only that the chemical supply tanks be kept filled. Personnel must be trained to monitor the system and service pumps and instrumentation.

The filtration systems are designed to be self-operating with automatic backwashing. Nevertheless, filters are susceptible to fouling and failure, and occasionally the filter media must be replaced. It will be necessary to train a technician in the operation of the filters. Specific skills needed include the ability to troubleshoot the filters, replace filter media, monitor the backflushing system, and recognize drops in throughput.

The GAC system is also designed to be self-operating, requiring only monitoring of pressure drop and effluent TOC. Personnel must be trained to replace the spent GAC, monitor the operation of the system, and service the pumps and other equipment.

When in use, the ion exchange system will be self-operating. Personnel training will include resin replacement, system monitoring, and pump and equipment servicing.

#### 7.5 RELATIONSHIP TO EXISTING TREATMENT FACILITIES

The 300 Area Process Sewer wastewater is currently being disposed in the 300 Area Process Trenches with no treatment prior to discharge. The L-045H treatment system, in addition to on-going efforts at source control, will replace the Process Trenches.

## 7.6 TREATMENT SYSTEM UNCERTAINTIES

There are a number of technical uncertainties which might reduce the treatment performance expected from the proposed L-045H treatment system. The following sections discuss four of those technical uncertainties and plans for minimizing their potential.

### 7.6.1 Design Wastewater Characteristics

Characterization of the 300 Area process sewer effluent is required to provide a basis for making treatment and disposal decisions. Complete characterization of the waste stream, however, is complicated by current and planned changes to the 300 Area Process Sewer wastewater sources.

In support of a Best Management Practices (BMP) approach, WHC has instituted a program of physical and administrative source controls and waste minimization of the 300 Area Process Sewer effluent. Implementation of the planned flow reduction and source control tasks will reduce the Process Sewer flow rate from about 4900 lpm (1300 gpm) to about 757 lpm (200 gpm), reduce the concentration of some of the constituents of concern, and reduce the potential for chemical spills. These activities are ongoing and will not be completed until shortly before the treatment facility is placed in operation. As a result, characterization data for the Process Sewer wastewater must be estimated from current chemical analyses after accounting for the effects of the proposed source controls and waste minimization efforts. These concentrations were calculated assuming a sewer flow rate of 1135 lpm (300 gpm) and were shown in Table 2-1.

Each of the unit operations included in the proposed system will be designed, primarily, based on these calculated reduced flow concentrations. However, the DOE intends to utilize results from a series of treatability tests to adjust the design parameters for the unit operations, as necessary, to maximize the probability for successful treatment.

The DOE is currently developing a treatability test program based on the expected wastewater characteristics and on the unit operations selected for use in the new system. The tests will utilize bench-scale or pilot-scale equipment to treat wastewater from the Process Sewer or wastewater adjusted to simulate the full range of contaminants and concentrations expected in feed to the treatment system. The test program will be designed to generate statistically-significant results which will be used by the contractor to adjust the preliminary design for the industrial-scale system.

### 7.6.2 Design Wastewater Feed Rate

The system design capacity and associated equipment sizing is based on wastewater flow rate. The design flow rate is based on estimates made regarding the results of on-going waste minimization programs in the 300 Area. Current plans call for reducing the current 4900 lpm (1300 gpm) flow to 757 lpm (200 gpm). The design flow rate for L-045H has been based on a flow rate of 1135 lpm (300 gpm). Therefore, the DOE is reasonably certain that the design flow rate is acceptably high.

### 7.6.3 Decontamination Factors

A decontamination factor (DF) is the primary measure of effectiveness of a given unit process for treating a given waste water contaminant. Specifically, an independent DF can be calculated for each species passing through a treatment process by dividing the concentration in the feed by the concentration in the effluent. In designing the L-045H system, engineers will have available a set of DFs projected from the treatability tests mentioned above. Therefore, each unit operation can be designed to achieve acceptable DFs for all constituents of interest based on L-045H wastewater characterizations developed to date. However, there is currently some degree of uncertainty in using DFs projected from the proof-of-concept treatability tests. Also, it is probable that target DFs for one or a very few constituents will determine the size and extent of equipment in each unit operation. For example, the target DF for a certain heavy metal may require that the system utilize two or more stages of co-precipitation rather than the one stage described above so that the overall DF through the system is sufficiently high. To accommodate a wide variety of scenarios, the facility layout will be designed with sufficient space so that one or more modules can be added in series in the future, if necessary.

## 7.7 SEPA/NEPA COMPLIANCE

The State Environmental Protection Act (SEPA) and National Environmental Protection Act (NEPA) require that environmental impact statements (EISs) be prepared for major actions significantly affecting the environment. Documentation addressing both NEPA and SEPA requirements have been prepared and are under review by appropriate authorities as outlined below.

Under NEPA requirements, where an action will not have a significant effect on the human environment, a Finding of No Significant Impact (FONSI) must be prepared accompanied by an environmental assessment (EA) supporting the finding. Such an EA has been prepared for the Hanford Environmental Compliance Project which includes the 300 Area treatment facility project. The EA is currently in the DOE comment resolution cycle. After the DOE resolves internal comments, the FONSI will be finalized and published before construction starts on the facility. The FONSI may also dictate environmental controls that must be designed into the facilities. If analysis of the EA indicates significant impact, an EIS will be prepared.

Under SEPA requirements, where an action is not categorically excluded, an environmental checklist is completed to aid the reviewer in identifying environmental impacts and determining if they are significant. A checklist which includes the 300 Area treatment facility project will be submitted to Ecology for review. Ecology actions can include a Determination of Nonsignificance, a Mitigated Determination of Nonsignificance, and a Determination of Significance. Ecology may require the submittal of additional information including the EA prepared for NEPA, or the submittal of a complete EIS.

## 8.0 SELECTION OF SECONDARY WASTE TREATMENT TECHNOLOGIES

Each of the five candidate primary waste water treatment systems described in Section 5 produces secondary waste streams. Regardless of which primary candidate is selected, those wastes must finally be disposed of by methods which are acceptable in terms of both economics and protection of the environment. As in most engineering applications, a number of alternatives exist for disposing of a given secondary waste stream. Depending on the form of the secondary waste, further treatment may be either necessary or beneficial prior to final disposal. Therefore, concurrent with the evaluation of the five primary treatment system candidates, a BAT evaluation was performed to identify a secondary waste treatment system for inclusion in the L-045H facility. This section documents that BAT evaluation and its results.

The evaluation included screening, comparing, and selecting alternative methods for treatment, if necessary, and for final disposal of secondary wastes. For simplicity, disposal system, whether or not they incorporate further on-site treatment, are referred to hereafter as treatment systems.

The following subsections document the BAT evaluation which proceeded, in steps, to characterize the secondary waste streams, establish treatment and disposal criteria, identify potential alternatives, derive and compare candidate systems, and select two proposed systems which target the two major forms of secondary waste. A number of alternatives include a significant degree of additional, on-site treatment. Others essentially transfer raw secondary wastes from the L-045H facility to other Hanford facilities for final disposal including any necessary further treatment to render the waste acceptable for disposal.

Much of the information used in the selection and preliminary design of the primary treatment system is, as yet, incomplete and subject to verification. For example, the quantities of chemicals to be added to promote precipitation in Alternative 4 or coagulation/flocculation in Alternative 5 and the properties of the resulting sludges will only be determined after completion of future treatability tests. Also, numerous options available to designers of the primary treatment systems may affect the characteristics of the secondary waste streams. Thus, the selection process described below for secondary waste treatment systems can only be characterized as preliminary. The candidate systems identified, compared, and selected below are subject to change or elimination depending on various factors including design options, specific vendor experience, and results of future treatability studies designed to verify the selection of primary and secondary treatment technologies.

### 8.1 CHARACTERIZATION OF SECONDARY WASTES

Each of the candidate primary treatment systems described in Section 5 produces solid and liquid secondary wastes in the course of normal operation. Major streams are produced continuously or semi-continuously and contain the bulk of the contaminants removed from the raw wastewater. Depending on the primary treatment process, the major streams are produced in two different forms - concentrated aqueous solutions or dewatered solids and sludges.

Minor streams are produced periodically and contain materials generated in conjunction with miscellaneous operating and maintenance functions. In general, these streams are produced in the form of dry solids. In cases where the solids have been in contact with wastewater (e.g., spent IX resin or RO membranes), they are cleaned via physical and/or chemical means to minimize residual contamination prior to disposal.

In identifying potential treatment systems, it is convenient to classify the secondary waste streams expected from the five candidate primary treatment systems into categories. One logical division of categories is according to physical characteristics. Therefore, for the purposes of this evaluation, the streams were grouped into three categories, each of which reflects, primarily, the predominant physical form. The following subsections describe the three waste stream categories.

### 8.1.1 Concentrated Aqueous Streams

Three of the five candidate primary treatment systems described in Section 5 above (Alternatives 1, 2, and 3) generate secondary waste streams consisting of concentrated aqueous solutions. In all cases, those solutions contain suspended and dissolved solids with trace quantities of residual organics. In all three alternatives, backwash from the filtration modules contributes equal quantities of suspended solids to the secondary waste streams. Also, the organics contents are essentially zero because each of the three primary treatment alternatives includes an effective organics-removal step which does not contribute to aqueous secondary waste. Furthermore, assuming that contaminants removed by the IX modules are added to the aqueous secondary waste streams via periodic regeneration of the IX resin beds, the dissolved solids contents of two of the three secondary waste streams are approximately equal. One of the alternatives has a higher dissolved solids content due to the addition of larger quantities of regeneration chemicals. Finally, each candidate includes an evaporator which produces a concentrated secondary waste stream containing 20 percent by weight of the mixture of the organics, suspended solids, and dissolved solids mentioned above.

These facts combine to make the three streams very similar in characteristics. Thus, from the standpoint of secondary waste treatment, they can be viewed as equivalent to each other for purpose of selecting a treatment technology.

The primary chemical and physical characteristics of the three concentrated aqueous streams are shown in Table 8-1. In each case, the figures include filter backwash as well as materials introduced by periodic IX regeneration. These materials include sulfate (from sulfuric acid) for cation resin and sodium (from sodium hydroxide) for anion resin.

No special physical parameters are anticipated in these aqueous secondary waste streams. The temperature should be near ambient (via supplemental heating, if necessary, during cold weather options). The pressure will be moderate depending on the discharge pressure of the transfer pump. Out-gassing should be minimal.

Table 8-1. Characteristics of Concentrated Aqueous Solutions

Characteristic	Alternative 1	Alternative 2	Alternative 3
Organic Compounds (kg/yr)	0	493	893
Inorganic Compounds (kg/yr)	520,000	112,000	112,000
Radionuclides (Ci/yr)	0.029	0.029	0.029
Flow Rate (lph)	260	56	56

### 8.1.2 Dewatered Sludge Streams

The two remaining candidate primary treatment systems, Alternatives 4 and 5, generate secondary waste streams in the form of dewatered sludge. In both cases, the sludge is processed through a filter press to yield a stream containing approximately 30 to 40 weight percent solids (on a dry basis) with the balance being water. The solids fractions include the suspended and dissolved solids removed from the raw wastewater along with the chemicals added to the primary treatment processes to induce precipitation or coagulation/flocculation. In the case of Alternative 5, the solids fraction also includes a substantial quantity of PAC added in the primary treatment process along with the organics adsorbed on the PAC.

The primary chemical and physical characteristics of the two sludge streams are shown in Table 8-2. In each case, the figures include materials introduced by upstream chemical additions required to promote precipitation or coagulation/flocculation. The parameters for Alternative 5 also include the PAC and adsorbed organics. Because the IX units in these two alternatives function as standby units only, the resins are not regenerated. Therefore, the sludges and the associated parameters in Table 8-2 do not include any materials associated with IX resin regeneration.

These sludge streams do not present any special physical challenges to be accommodated in the selection of or design of a secondary waste treatment system. They are produced at essentially ambient temperature (augmented by supplemental heating, if necessary, during the cold weather operations). They are adaptable to gravity flow, with or without the aid of mechanical conveyors. Therefore, transport pressure is not a consideration. Out-gassing should be minimal.

### 8.1.3 Miscellaneous Solid Wastes

The third category includes miscellaneous solid wastes generated periodically in association with routine operation, maintenance, and administration of the L-045H facility. This category would include process materials such as saturated GAC, spent IX resin,

Table 8-2. Characteristics of Sludge Streams

Characteristic	Alternative 4	Alternative 5
Organic Compounds (kg/yr)	0	3400
Inorganic Compounds (kg/yr)	24,000	300,000
PAC (kg/yr)	0	120,000
Radionuclides (Ci/yr)	0.026	0.026
Flow Rate (lph)	9.8	60

plugged filter elements, and plugged RO membranes. It would also include other materials such as worn-out or damaged mechanical equipment, discarded personal-protection clothing, and housekeeping trash from buildings and grounds. Using routine procedures, these materials can be readily disposed of.

Beyond cleaning followed by dewatering and/or drying, the process materials require little or no further, on-site treatment prior to disposal. Rather, as part of the primary treatment process they are cleaned while still in place inside the process vessels. The cleaning typically consists of rinsing with clean water, and may include after-rinsing (or regenerating) with appropriate chemical solutions. After cleaning, the materials are removed, dewatered or dried as necessary, packaged, and transported to an on-site disposal facility or storage facility according to established procedures. As mentioned in Section 5, saturated GAC is returned to the vendor's facility or to an on-site facility for regeneration or disposal. When regeneration is no longer feasible due to plugged pores, the GAC is disposed of in accordance with policy and regulations.

General trash designated as nonhazardous waste is disposed of in solid waste landfills. The disposal process typically consists of periodic collection from bins, segregation by type, packaging, and transportation to the landfill. All these steps are supervised and performed according to methods incorporated in the L-045H facility operating procedures. Because of the simple and orthodox nature of the disposal procedures, as a category, general trash, as a category, is not given further consideration in terms of secondary waste treatment system selection.

## 8.2 SECONDARY WASTE TREATMENT CRITERIA

Due to the presence of heavy metals, the three concentrated aqueous streams and the two dewatered sludge streams described above are assumed to be hazardous wastes according to existing federal and state regulations. Of the five streams, only those in liquid form require significant further treatment to meet typical hazardous waste landfill acceptance

criteria. However, additional treatment of the sludges could offer benefits to the DOE in terms of operating efficiency.

Two objectives of additional treatment for the aqueous streams are volume reduction and physical stabilization. In general, the most acceptable final form for hazardous secondary waste is dry solids sealed in corrosion-resistant packaging. A number of evaporation technologies exist which could be used to convert the aqueous streams into dry solids. A number of technologies exist for concentrating or extracting and solidifying contaminants contained in liquid waste streams. Most of the technologies have been used successfully in various industrial applications. This BAT evaluation concentrated on demonstrated technologies.

On the other hand, disposal of the sludge streams presents no insurmountable problems assuming that they can be drained of water so that the resulting material meets the EPA paint filter test for the presence of free moisture. However, the sludges are adaptable to further treatment, if necessary, to increase the range of flexibility in final disposal methods.

Identification and selection of BAT for secondary waste treatment depends on a number of factors, some of which are:

- Chemical composition;
- Volumetric flow rate;
- Targeted characteristics (particle size, moisture content, etc.);
- Economics;
- Utility requirements;
- Environmental constraints; and
- Waste minimization.

This list is not comprehensive. However, it is indicative of the number of project-specific parameters that affect the choice of technologies to treat a given secondary waste stream.

In the case of the L-045h project, the design information used in defining the candidate primary treatment systems is preliminary at this stage. Hence, the secondary waste characteristics described above are subject to confirmation or revision. Given that uncertainty, it is only possible to establish general criteria for selection of secondary waste treatment technology. To date, five criteria are presented below:

1. Mechanical and Technological Maturity:

Principal equipment items and process technology incorporated in the treatment system must be commercially demonstrated and available in order to support the objectives of the Hanford Site Environmental Management Mission. Specifically, the system must embody sufficient maturity to facilitate design, construction, and startup within the timetable established in the Tri-Party Agreement.

2. Physical and Chemical Stability:

The treatment system must provide reasonable assurance that acceptable chemical and physical stability will be achieved and maintained in the treated waste to satisfy conditions imposed by operators of on-site or off-site transport, storage and disposal facilities.

3. Minimum Mass and Volume:

The treatment system must produce the smallest mass and volume of final waste(s) consistent with economic feasibility.

4. Ambient Air Quality:

The treatment system must incorporate proven technology and operating procedures as necessary to prevent degradation of ambient air quality.

5. Safety:

The process technology, equipment, and operating procedures utilized in the treatment system, individually and in combination, must provide superior levels of operator, public, and environmental safety.

### 8.3 SCREENING OF SECONDARY WASTE TREATMENT ALTERNATIVES

Application of the Technology Transfer Method contained in the DOE's BAT selection procedure identified a number of alternatives for secondary waste treatment. The alternatives were evaluated against the five essential criteria specified above. Alternatives with potential for meeting the criteria were retained as candidates for further evaluation and comparison while the others were eliminated from further consideration. The following subsections describe the alternatives and indicate the results of the initial screening in terms of whether each was retained for or rejected from further consideration.

#### 8.3.1 No Action

In general, the raw secondary waste streams generated by the five primary treatment alternatives fall into two categories. The first category includes relatively concentrated, aqueous solutions containing dissolved solids, suspended solids, and trace quantities of residual organics. The second category includes moist but physically stable filter cake containing the impurities mentioned above as well as chemicals added during primary treatment to promote precipitation or coagulation/flocculation. Raw streams in the former of these two categories would be classified as liquid wastes according to typical waste acceptance criteria. Because Hanford Site procedures make no provisions for on-site disposal of liquid wastes and off-site landfills are also restricted from accepting liquid wastes, No Action is not a viable alternative for the secondary waste forms containing liquid.

### 8.3.2 Off-site Disposal

In the context of this evaluation, off-site disposal consists of paying a vendor (per unit of mass or volume) for off-site disposal of a given secondary waste stream. The vendor provides equipment to receive batches of secondary waste from on-site storage facilities and to transport the material to his facilities. If further treatment is necessary prior to final disposal, the vendor provides all technology, facilities, and/or labor required. Finally, the vendor permanently disposes of the material using established procedures in accordance with local, state, and federal air and water quality regulations.

There are uncertainties regarding future liability associated with off-site disposal of wastes containing trace levels of radioactive materials. Off-site disposal was not considered further in this evaluation due these potential liabilities. Costs of off-site waste disposal are lower than costs of on-site disposal, however. Therefore, off-site disposal should not be ruled out in the final disposal plans, pending resolution of the liability issues.

### 8.3.3 On-site Grouting

Grouting is a term the DOE applies to a process in which solid and/or liquid waste streams are used as raw material in a mortar-like slurry which eventually hardens into stable, solid material with properties similar to those of ordinary concrete. In a typical grouting process, an aqueous waste stream is mixed with cementitious materials and various chemical additives to form a grout slurry. However, the process can generally be adapted to accept sludges rather than aqueous solutions. The grout slurry is pumped into a holding vault (a lined, subterranean pit) where it dries and hardens. The end product has physical and chemical stability and, typically, resistance to leaching.

The DOE currently operates a grouting system which facilitates disposal of waste slurries generated in the course of numerous activities associated with the Hanford Site Environmental Management Mission. In the existing system, wastes that have been successfully grouted include solutions containing phosphates and sulfates. Grouting each stream requires the use of a specific formulation (recipe) of chemical additives which has been developed to accommodate particular impurities in that stream.

It is conceivable that secondary waste streams from any of the five alternatives for primary waste treatment could be routed either to the existing DOE grouting facility or to new grouting facilities. The existing facility was designed to grout a limited volume of slurried wastes having chemical compositions within specific ranges. Therefore, it is not certain whether there is sufficient capacity and chemical flexibility to grout the additional wastes from the L-045h facility. If the is available, it would still be necessary, at a minimum, to develop new operating techniques and additional recipes to obtain a stable end product based on this waste. Developing modifications to the process to accommodate sludge may be particularly challenging in view of its tendency to settle in large feed tanks.

In summary, technology and equipment similar to those required for grouting aqueous L-045H facility secondary wastes have been demonstrated at the Hanford Site. Also, it is possible that the existing facility has sufficient excess capacity to treat additional wastes at

minimal incremental cost. Finally, there is the potential for adapting the process so that it can accept waste sludges. Therefore, on-site grouting was retained as an alternative means of treating either form of secondary waste which could result from operation of the L-045H facility.

#### 8.3.4 Off-site Grouting

The possibility exists for off-site grouting and disposal of L-045H facility secondary wastes. The primary functions associated with this technology would be performed by an off-site vendor. Potential systems typically include mixing and placing the waste stream with other raw materials and additives in disposable liners rather than in vaults. The liners are constructed of mild steel or heavy plastic and may be equipped with disposable mixing mechanisms, thermocouples, and material injection components. After the material hardens, operators sever the various process and control connections to the liner and then dispose of the liner and its contents in a specialized landfill. With this technology, empty liners could be brought to the L-045H facility and full ones transported off-site by the vendor for disposal. Alternatively, the raw waste stream could be transported off-site to the vendor's facilities.

The high expense of the liners and their auxiliary equipment makes this option a very costly one. Also, in the case of waste sludge, the technical challenge of developing grouting recipes is somewhat uncertain. Moreover, there are liability issues associated with disposal of wastes containing trace levels of radioactive materials. Therefore, off-site grouting was not given further consideration as a means of treating L-045H secondary wastes.

#### 8.3.5 Evaporative Crystallization/Centrifugal Dewatering

Evaporative crystallization is a process which uses heat to evaporate water from an aqueous feed solution containing suspended and/or dissolved solids. The evaporation continues beyond the maximum equilibrium concentration (saturation) points for the respective dissolved solids species. A brine chamber provides cooling and residence time to promote crystal growth in the supersaturated solution.

Solution containing crystals (as well as any suspended solids present in the feed stream) is extracted from the brine chamber and sent to a dewatering centrifuge. A high-speed spinning motion in the centrifuge creates centrifugal force which, based on the differences in specific gravities, acts to separate crystals and suspended solids from the carrier solution. The centrifuge produces two exit streams. The first, sludge, has a paste-like consistency and contains 30 to 40 weight percent solids in aqueous, saturated solution. The second, concentrate, consists of relatively-pure saturated solution. If necessary prior to final disposal, sludge is sent to downstream equipment for draining and packaging. Concentrate is returned to the evaporator where it is mixed with fresh feed solution and recycled in this process.

This technology has been applied to numerous streams having properties similar to those of the L-045H facility aqueous secondary waste streams. Therefore, it was retained for further evaluation.

### 8.3.6 Spray Drying

Evaporative concentration, as it may be applied in the L-045H facility, was described in Section 5. The process was included in three of the candidate primary treatment systems (Alternatives 1, 2, and 3) to produce concentrated aqueous secondary waste streams from dilute aqueous feed solutions. In each of those alternatives, the output from an evaporator was an aqueous liquid stream containing 20 weight percent total solids. That concentration limits any of the given dissolved solids species to a maximum of 90 percent saturation. Thus, there are no problems associated with formation of solid crystals from dissolved solids.

Spray drying is a process which can separate aqueous solutions into two streams, relatively-dry solids and relatively-pure water. In a typical spray dryer, the high heat content and low relative humidity of a stream of hot drying gas promote evaporation of essentially all of the water. The resulting mixture of gas and water vapor is filtered to capture dry solids prior to venting to the atmosphere. Captured solids are transported to downstream equipment for packaging.

The hot gas stream delivers the total heat duty to the drying vessel. The drying gas (typically air) may be heated by any conventional means capable of attaining a temperature in the range of 480 to 650 °C (900 to 1200 °F). One potential source of heat is direct firing of natural gas or propane. In that type of system, the hot flue gases from the combustor mix with air to form the hot drying gas. Another potential source of heat is a bank of electric heating elements which would heat a stream of air.

The technological and economic effectiveness of spray drying have been proven in numerous industrial applications drying aqueous feed streams. Therefore, spray drying was retained for further evaluation as technology for treatment of L-045H aqueous secondary wastes.

### 8.3.7 Wiped-film Evaporation

Wiped-film evaporation has been used in numerous industrial applications to separate aqueous feed streams into dry solids and water vapor. In practice, an aqueous solution of dissolved and/or suspended solids is fed into the evaporator. The feed stream is distributed, as a thin film, across a heated surface. The heat evaporates most of the water fraction, leaving behind a crust of near-dry solids. A mechanical device periodically wipes the solids into a collection hopper to await transport to downstream packaging equipment.

Wiped-film evaporators have been designed in various configurations including both vertical and horizontal heating surfaces. The process requires a heating medium, typically low-pressure steam, at a temperature significantly higher than the boiling point of the feed stream to effectively evaporate the water fraction. However, the process is also capable of using electrical heating elements. This technology was considered applicable to the L-045H facility aqueous secondary wastes and was retained for further evaluation.

### 8.3.8 Vacuum-Freezing Multiple-Phase Transformation

This technology, commonly referred to as freeze drying, was described briefly in Section 4. In industry, the process has been successfully applied to the concentration and/or separation of numerous streams having characteristics analogous to those of the three L-045H facility aqueous secondary waste streams. Based on those applications, it has the potential for producing dry solids which could be packaged for disposal in a hazardous waste landfill. Therefore, it is seen as a viable alternative and was retained for further evaluation as a secondary waste treatment technology.

## 8.4 SCREENING SUMMARY

Table 8-3 presents a summary of the decisions discussed above regarding whether each alternative treatment process was to be retained for further evaluation or eliminated from consideration. The table also indicates which technologies are suitable for treating which forms (i.e., aqueous or sludge) of waste.

## 8.5 CANDIDATE SECONDARY WASTE TREATMENT ALTERNATIVES

Several alternative secondary waste treatment systems discussed in the previous section were retained as candidates for further evaluation. Each of the candidate systems has the potential for satisfying the five essential project criteria. As indicated in Table 8-3, certain of the technologies are suitable for application in treating either aqueous or sludge streams, while others are only effective in treating only one form or the other. Therefore, at this point, the BAT evaluation diverges to consider the candidates in terms of which of the two identified as suitable for treating sludges. Similarly, Section 8.5.2 describes candidates suitable for treatment of aqueous streams. The individual presentations outline process trains based on the preliminary information available and briefly describe how the systems would function as a part of the L-045H treatment facility.

### 8.5.1 Candidates for Treatment of Sludges

Sludges are produced by the primary filtering process in all alternatives and by the secondary waste filtering process employed in Alternatives 4 and 5. The following subsections describe the two technologies selected for further evaluation.

#### 8.5.1.1 No Action

The filtering processes will yield waste sludges that are expected to be chemically and physically stable. The filtered sludge is expected to resemble damp clay. Normally this material will not contain free water. Controls or design features can be employed to ensure that sludge emplaced in disposal containers will not contain drainable water. A desiccant or sorbant may be added to disposal containers to provide assurance that any free water present will be eliminated.

Sludges from both filtering processes are expected to be largely insoluble and free of significant levels of organics. (The organics will be captured on PAC or GAC) The sludges

Table 8-3. Screening Summary: Secondary Waste Treatment Technologies

Treatment Technology	Aqueous Streams		Sludge Streams	
	Eliminated	Retained	Eliminated	Retained
No Action	•			•
Off-site Disposal	•		•	
On-site Grouting		•		•
Off-site Grouting	•		•	
Evaporative Crystallization/ Centrifugal Dewatering		•	•	
Spray Drying		•	•	
Wiped-film Evaporation		•	•	
Vacuum-freezing Multiple-phase Transformation		•	•	

may be sufficiently insoluble to pass EPA's Toxic Characteristic Leaching Procedure which, if so, may qualify the sludges for disposal without further treatment.

The facilities for sludge handling include an inclined table and raking device that enables water and very wet sludge to drain to a recycle tank. Damp sludge will be raked into disposable containers or plastic-lined beds of dump trucks.

On-site procedures include analyzing sludge samples on a prescribed schedule to provide the disposal or storage facility operation with the required data on waste characteristics. Routine monitoring of conveying and storage systems (both visually and with leak-detection instrumentation) will be conducted to prevent accidental spills. L-045H operators will record pertinent data and label each batch of material shipped. All maintenance functions are designed to minimize personnel contact with surfaces which have contacted sludge.

### 8.5.1.2 On-site Grouting

The operating experience of an existing grouting facility at the Hanford Site suggests the possibility of grouting L-045H sludge. Assuming technical and economic feasibility, grouting produces a stable, solid material with properties similar to those of concrete. In an on-site grouting process, the sludge is mixed with cement-like material and one or more chemical additives. Pumps transfer the resulting grout slurry into vaults where chemical hydration reactions harden the material, over a period of time, into a solid. The resulting structure yields a stable solid with substantial resistance to leaching. The vault liners act as secondary containment barriers to minimize leaching by water in the vadose zone.

The equipment required for this alternative includes sludge conveyors and a surge tank as described in Section 8.5.1.1. The dewatered sludge is not expected to be pumpable. Therefore, less efficient filtration methods will be employed to enable pumping the sludge to the grout plant. This alternative could include an entirely new grouting facility if the existing Hanford system does not have surplus capacity to handle the L-045H facility material or is not adaptable to the recipe(s) required for grouting sludge rather than liquid waste. In either case, suitable grout slurry recipes must be developed and the properties of the end product must be tested.

## 8.5.2 Candidates for Treatment of Aqueous Streams

The evaporators included in Alternatives 1, 2, and 3 produce concentrated aqueous waste streams containing 20 weight percent solids. In all cases, the streams are expected to be chemically stable. However, because they are liquids, they do not meet acceptance criteria for disposal in hazardous waste landfills. Therefore, it is necessary to convert the material to a solid form prior to disposal. A wide range of technologies exists for such conversion. The following subsections describe the conversion technologies identified in this evaluation.

### 8.5.2.1 On-site Grouting

Experience at Hanford with grouting laboratory solutions containing about 20 percent dissolved solids indicates strong potential for successful grouting of L-045H facility aqueous wastes. The assumption of technical and economic feasibility is safer for aqueous wastes than for sludge.

The equipment and processing steps used in this alternative are similar to those described for sludge grouting in Section 8.5.1.2. This alternative would include an entirely new grouting facility only if the existing system does not have sufficient surplus capacity and operating flexibility. As with sludge, time and money will be required to develop new grout recipes and to test the properties of the end product.

### 8.5.2.2 Evaporative Crystallization/Centrifugal Dewatering

This alternative consists of two processes operating in series. The first process is evaporative crystallization which produces a slurry of crystals from dissolved solids along with the suspended solids present in the aqueous waste. The second is centrifugal dewatering which produces damp cake which, with addition of suitable desiccant, can be disposed of as dry, solid material.

The equipment train begins with an inlet surge tank which provides storage capacity and equalization for the aqueous stream received from the evaporator in the primary treatment system. The surge tank is also used for any necessary stream conditioning such as pH adjustment. The evaporator consists of two or more stages of adiabatic flash evaporation. It is specifically designed to concentrate the aqueous waste stream by removing water until the dissolved solids concentration rises above the saturation point. The final stage consists of a brine chamber where crystals are formed from the supersaturated brine solution. The brine chamber is sized to provide the residence time required of optimal crystal growth during each pass of liquid through the vessel.

The evaporator is a mechanical vapor recompression (MVR) unit which assures maximum energy efficiency. The key element of MVR is compression of the water vapor resulting from the evaporation process. Compression raises the heat content and lowers the dew point of the vapor so that it can be recycled to the evaporator as heating medium. Essentially, the MVR process converts electrical energy supplied to the vapor compressor motor into thermal energy carried by the compressed vapor. A bank of electric heating coils provides startup heat for the process.

The output from the crystallizer is a slurry containing about 30 weight percent suspended and crystallized solids with the balance being saturated brine solution. The stream flows into a surge tank. The surge tank is equipped with a turbine mixer to maintain solids in suspension and an electric heater to avoid freezing during cold weather operation. A pair of diaphragm pumps (one operating and one standby spare) transfers slurry to the dewatering centrifuge.

The centrifuge is either a solid-bowl or a disk-stack unit, depending on the abrasiveness of the solids. A motor-driven shaft rotates the bowl (or disks) of the centrifuge at high speed. The rotation creates centrifugal force which exerts a force on the suspended solids equal to several thousand times that of normal gravity. The force acts to separate and stratify the mixture based on the relative densities of the solids and the carrier solution. A stream of saturated solution is extracted from the centrifuge and returned to the evaporator for reprocessing. The remaining cake contains about 10 weight percent water with the balance consisting of solids present in the evaporator feed stream. In operation, a given quantity of aqueous waste feed to the system passes through the crystallizer and centrifuge numerous times with a fraction of the contaminants being removed as solid cake at the end of each pass.

A mechanical conveyor transport centrifuge cake to downstream equipment for packaging prior to disposal. The packaging system consists of a standard storage bin, a

weigh scale, and a mechanical conveyor required to place measured quantities of cake into one-site. If necessary, packaging will include addition of a desiccant to absorb any free water in the raw cake.

### 8.5.2.3 Spray Drying

A pair of corrosion-resistant, centrifugal pumps (one operating and one standby spare) included in the primary treatment system transfers concentrated aqueous waste from the evaporator to a surge tank located in the secondary waste treatment system. The purpose and configuration of the surge tank are essentially identical to those described above in Section 8.5.2.2. Another pair of pumps feeds aqueous solution to the spray dryer.

Inside the spray dryer vessel, a set of fixed nozzles (or rotating-disk) atomizes the feed stream and directs the resulting mist into a countercurrent stream of hot drying gas. The vessel volume provides sufficient residence time for evaporation of essentially all of the water, leaving behind dry solids.

The energy required for spray drying is approximately 830 kcal/kg (1,500 Btu/lb) of water evaporated. That figure accounts for the minor contribution from heats of crystallization (typically, exothermic reactions) associated with conversion of the various dissolved solids into crystals. All of the net energy requirement is transferred to the aqueous feed stream within the drying vessel. The quantity and species of crystals expected from evaporation of a given volume of aqueous waste are not yet known. However, as an example, the heat evolved by the exothermic reaction of calcium and chloride ions in the process of crystallizing to form calcium chloride ( $\text{CaCl}_2 \cdot 2\text{H}_2\text{O}$ ) is approximately 12.5 kcal per gram mole of crystal produced.

In the L-045H application, the drying gas is ambient air. The air serves as the medium for delivery of energy to the dryer. Prior to entering the drying vessel, the air is heated to a temperature of about 500 °C (930 °F) by a bank of electric heating coils. A stream of solids-laden air and water vapor exits the spray dryer through a baghouse filter which captures dry solids. The cooling effect of evaporation results in a mixture temperature low enough to avoid damage to the filter bag fabric. Before venting to the atmosphere, the filtered gas stream passes through a condenser which cools the gas and condenses a large portion of the water vapor. In the interest of energy conservation, the condenser acts as a pre-heater for the incoming ambient air stream.

Automated cleaning cycles in the baghouse release solids from the bag surfaces and drop them into a storage hopper. A screw conveyor removes accumulated solids from the hopper and transports them for packaging.

The packaging system consists of a drum-filling station, including a weigh scale, placing measured quantities of dry solids into drums. After sealing, the drums are disposed of in a hazardous waste landfill.

#### 8.5.2.4 Wiped-film Evaporation

This process is similar to that described above for spray drying. The primary difference is that drying takes place on a fixed heating surface rather than in a moving gas phase. As with spray drying, a pair of corrosion-resistant, centrifugal pumps (one operating and one standby spare) included in the primary treatment system transfers concentrated aqueous waste from the evaporator to a surge tank located in the secondary waste treatment system. The purpose and configuration of the surge tank identical to those described above in Section 8.5.2.2. Another pair of pumps feeds aqueous solution to the wiped-film evaporator.

Inside the evaporator, a weir continuously distributes the feed stream as a thin film across a heated surface. The heated surface consists of large-diameter heat transfer tube. The heating medium, compressed water vapor, surrounds the outside of the tube. The evaporation of water deposits a nearly-dry crust onto the tube surface. The crust is composed of crystals formed from dissolved solids in the feed stream as well as suspended solids present in the feed. A set of blades or paddles rotate around the centerline of the tube wiping the surface to remove the crust. The blades are inclined to provide mechanical conveying as well as solids removal. The disengaged crust drops into a storage hopper located below. An auger conveyor transports dry material from the hopper to the downstream packaging system. The evaporator incorporates MVR for energy efficiency. The heat of the compressed vapor serves to preheat the incoming aqueous feed stream. During startup, a bank of electric heating coils provides heat until the MVR process is established.

The packaging system consists of a standard bin, a weigh scale, and an auger conveyor required to feed weighed batches of solids into drums. After sealing, the drums are disposed of in a hazardous waste landfill. If necessary, desiccant is added to the drums to absorb free moisture.

#### 8.5.2.5 Freeze Drying

This process train begins with a surge tank to store aqueous waste from the primary treatment system. The tank provides equalization and surge capacity. A pair of centrifugal pumps delivers a continuous flow of solution from the tank to the freeze drying chamber.

A pair of vacuum pumps (one operating and one standby spare) evacuates the freezing chamber to create vacuum. Inside the freeze drying chamber, severely cooling the feed stream at vacuum conditions vaporizes a portion of the entering water and freezes the balance. Solids remaining after vaporization of the water phase are not readily soluble in ice. Therefore, freezing produces a residue of ice and dry solids. The solids consist of suspended solids as well as crystallized salts formed from dissolved solids present in the aqueous feed stream. The ice and solids are mechanically separated. Prior to melting, the ice is washed in a tower to rinse solids from its surface. The heat content of the water vapor from the freezing chamber is used to melt the ice from the washing tower. The melted water phase is returned to the primary wastewater treatment system for reprocessing. The dry solids are mechanically conveyed to downstream packaging equipment.

The freeze drying system includes auxiliary equipment such as refrigeration compressors, heat exchangers, miscellaneous liquid pumps, and solids conveyors. The large number and variety of equipment items makes these the most equipment-intensive among the alternatives considered.

## 8.6 COMPARISON OF CANDIDATE TREATMENT SYSTEMS

The candidate system for secondary waste treatment were compared against criteria somewhat different from those applied in Section 6 to the candidates for primary waste treatment. In particular, the quantities and qualities of the various secondary waste streams are not sufficiently defined at this point to support any relevant cost comparison.

The six criteria used in the comparison were chosen to reflect the type of system required for reliable, long-term service in meeting the anticipated disposal standards. Each criterion was assigned a weighting factor on a scale of 1 to 10, with 10 representing the highest ranking. The criteria categories are discussed below.

- **Flexibility**

Flexibility concerns the ability of the process technology or the individual equipment items to adapt to changes in raw secondary waste flow rates and/or compositions. Flexible processes continue to achieve functional targets 1) while operating at capacities significantly below their design values and 2) when the waste stream composition varies substantially from the average design point. In this evaluation, the characteristics of the secondary waste from a given primary treatment alternative are expected to be relatively uniform. Therefore, the ability to achieve a large process turndown and to operate successfully with variable feed compositions is only moderately important and rated a weighing factor of 7.

- **Reliability**

Reliability, as measured by system operating efficiency (on-stream time), is a combination of process reliability and equipment reliability. Process reliability reflects the ability of the technology to reliably process the secondary waste without undue operating complexity. In other words, the system should perform well within a comfortable range of conditions rather than relying on operators to maintain a fine balance for one or more of the operating parameters. Equipment reliability reflects the potential for equipment failures taking into account basic process parameters such as the presence of extreme temperature or pressure conditions, the reliance on rotating equipment, the type of construction materials, and the degree of design experience presented by the technology vendor(s). The weighing factor of 9 applied to this criterion reflects its importance in achieving L-045H Project objectives.

- **Safety**

Safety is a measure of system's ability to achieve the operating targets without exposing plant personnel, the public, and the surrounding environment to undue risk. Safety can be inherent in the process (e.g., the absence of elevated temperatures or pressures) or it can be achieved through careful equipment design and strict adherence to safe, established operating procedures. Typically, process systems achieve acceptable safety through a combination of those two methods. Safety is considered essential to the success of the L-045H Project and the criterion was weighted at 10.

- **Technical Viability**

Technical viability reflects the maturity level of the process technology. One of the five essential criteria for potential secondary waste treatment systems was that the technology and equipment have been demonstrated in one or more similar industrial applications. This criterion was considered to be very important and was weighted at 10.

- **Ease of Maintenance**

Ease of maintenance is an assessment of how easy or difficult it is to maintain a given process over the life of the project. Simple systems are typically more easily maintained than complicated ones. Because of the requirements for operating efficiency and minimal personnel exposure to contaminated equipment, this criterion was deemed to be fairly important and was given a weighing factor of 6.

- **Containment**

The containment criterion reflects the potential of the system for spilling or leaking vapors and liquids into the surrounding atmosphere. A system with a large number of pumps, compressors, valves, filters, and other fluid-containment mechanisms has a higher probability of developing leaks which require cleanup and follow-on maintenance. Systems that require a large number of steps involving transfer of materials are more likely to experience spills.

The secondary waste treatment system should be as integral as possible to minimize the probabilities for operator exposure to toxic constituents and for lost production due to leak repair and cleanup activities. Having a high probability for maintaining total containment, whether in liquid, solid or gaseous form, was assessed to be reasonably important; hence the 7 weighing.

Each candidate system was then assigned a score of 1 to 3 for each criterion. The scores represent low, medium, or high, with a score of 3 representing the highest ranking. Both the weighing factors and the scores were quite subjective in nature due to lack of design information specific to the potential secondary wastes. However, qualitative differences

among the Table 18a System are Municipality Selected in Waste Treatment Alternatives in Table 18a.

Criterion	W e i g h t	Sludge Alternatives				Aqueous Waste Alternatives	
		No Action		On-site Grouting		On-site Grouting	
		Raw	Score	Raw	Score	Raw	Score
Flexibility	7	3	21	1	7	2	14
Reliability	9	3	27	2	18	3	27
Safety	10	2	20	2	20	2	20
Technical Viability	10	3	30	1	10	1	10
Ease of Maintenance	6	3	18	2	12	2	12
Containment	7	3	21	3	21	3	21
<b>Total Score</b>			<b>137</b>		<b>88</b>		<b>104</b>

Criterion	W e i g h t	Aqueous Waste Alternatives (cont.)					
		Evaporative, Crystallization/ Centrifugal Dewatering		Spray Drying		Freeze Drying	
		Raw	Score	Raw	Score	Raw	Score
Flexibility	7	3	21	3	21	2	14
Reliability	9	2	18	3	27	2	18
Safety	10	2	20	2	20	2	20
Technical Viability	10	3	30	3	30	1	10
Ease of Maintenance	6	1	6	2	12	1	6
Containment	7	2	14	3	21	1	7
<b>Total Score</b>			<b>109</b>		<b>131</b>		<b>75</b>

Notes: Rating 3 = High  
 Rating 2 = Medium  
 Rating 1 = Low  
 All ratings are relative to the technology choices as shown.

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The total scores indicate that No Action is the alternative that best meets the requirements for sludge; Spray Drying is the preferred alternative for aqueous waste.

## 9.0 PROJECT IMPLEMENTATION AND FACILITY ADMINISTRATION

The timetable associated with implementing the L-045H Project and the responsibilities for ownership, operation, and administration of the completed facility are addressed below.

### 9.1 PROJECT IMPLEMENTATION

Successful and timely completion of Project L-045H is essential to achieving the objectives of the Hanford Site Environmental Management Mission and of the Tri-Party Agreement. To define a schedule for L-045H, the DOE has begun dividing the overall project implementation into a matrix of interrelated tasks. The individual tasks encompass environmental permitting, treatability testing, process design, equipment procurement, construction, personnel training, and facility commissioning. Currently, treatability tests are in progress to demonstrate the technical viability of Alternatives 4 and 5 among the candidate systems for primary waste water treatment. The results of those tests will have a large bearing on the timetable for final process selection and project implementation. Therefore, a detailed timetable is not available at this time. When completed, a timetable will be submitted as an addendum to this report.

### 9.2 FACILITY OWNERSHIP AND OPERATION

The treatment facility resulting from execution of Project L-045H will be a United States Government installation administered by the DOE. In administering the facility, the DOE intends to assign operating and maintenance responsibilities to one or more subcontractors. The subcontractor(s) will operate and maintain the facility in accordance with technical and administrative criteria and procedures as determined and routinely updated by the DOE. The potential subcontractor(s) will be limited to those who have demonstrated expertise in operating and maintaining equipment and processes having complexities similar to those utilized in the L-045H facility. Such subcontracts for operation and maintenance are typical and have proven successful for facilities under DOE control at Hanford as well as at other United States Government installations.

During an initial period of operation (possibly a few months), the DOE will retain a group of vendor employees to assist the subcontractor(s) in various activities including training, detecting and correcting operational abnormalities or deficiencies, and updating preliminary operating and maintenance procedures. The assistance group will be comprised, as necessary, of employees or representatives of companies associated with all phases of the project including technology development, design, engineering, equipment fabrication, and construction.

## 10.0 PROFESSIONAL ENGINEERING ASSESSMENT

The technology proposed by the DOE for Project L-045H was derived via a thorough evaluation of a large array of technological alternatives which, individually or in combination, offered the potential for treating the constituents of concern. The many scientists and engineers, both within Westinghouse Hanford Company and the independent consulting engineers who participated in the selection of technologies and in the preparation of this report are collectively confident that the completed system will treat those constituents to levels which meet or exceed any set of reasonable criteria, yet will operate with a high degree of safety, reliability, and flexibility.

The following sections explain the source of that confidence from three perspectives. Section 10.1 offers an assessment of the BAT evaluation procedure which was applied to select the process technologies to be incorporated in the proposed facility. Section 10.2 discusses the probability for acceptable treated water quality. Section 10.3 emphasizes several measures embedded in the project implementation plan which will minimize technical risks associated with the facility, thus maximizing expectations for safe, consistent, and effective waste treatment.

### 10.1 BAT EVALUATION PROCEDURE

As professional engineers experienced in wastewater treatment, we participated in discussions regarding the evaluation program employed by the DOE, WHC, and their various subcontractors in identifying, screening, and selecting the process technologies to be used in Project L-045H. In preparing this report, we examined and assessed the BAT procedure which the DOE has developed and applied consistently and uniformly to all technical evaluations of this nature. The BAT procedure was determined to be a valid codification of comprehensive, precise, and impartial methods for applying engineering judgement and discipline to the selection of technologies.

A thorough review of the many documents which, collectively, present the results of the BAT evaluation for Project L-045H indicate that the procedure was applied carefully and will result in the best possible treatment system given the state of current technology. The documents also clearly indicate that application of the BAT procedure to Project L-045H included full peer review at each decision point to ensure that relevant information was not overlooked or misinterpreted. Moreover, numerous supporting documents indicate that the search for technologies was conducted with impressive depth and breadth. Those documents include: extensive references to relevant engineering and scientific publications; reports of field trips to assess pilot- and commercial-scale operating results; reports of interviews with potential process vendors; and reports of field trips and interviews to assess technologies which are being used to treat waste streams with similar characteristics at other DOE facilities including Oak Ridge National Laboratory and the Savannah River Site. In addition, proof-of-concept treatability studies were performed, with evaluation of the results leading to final technology selection. This procedure corresponds to step four in the BAT evaluation process.

## 10.2 APPROPRIATE PROCESS TECHNOLOGIES

The pretreatment, treatment, and post-treatment process technologies which comprise the proposed L-045H treatment facility were described in detail in earlier sections of this report. In addition, Best Management Practices (BMP) and source controls were identified for implementation to reduce the waste stream quantity. In general, the chosen technologies appear to be demonstrated, available, and appropriate for addressing the waste streams. Most of the technologies also offer a reasonable degree of flexibility for accommodating substantial variations in the volume and concentrations of wastewater impurities. Such process flexibility is an important asset of the proposed system. At present, flexibility is required to accommodate unknowns in the wastewater characteristics.

Many of the BMP's and source controls for the proposal project are not presently implemented. The wastewater contaminant concentrations cannot be fully defined until these practices are implemented. Flexibility of the treatment process is required to accommodate variations in the actual concentrations from present projections. In the future, the same flexibility provides the DOE with a degree of freedom to implement changes in equipment and operating procedures in the processes which produce the wastewater streams. Such changes could offer significant advantages to processing capacity or efficiency, thus improving the timetable and reducing costs of the Environmental Management Mission at Hanford.

## 10.3 PROJECT IMPLEMENTATION

The DOE plan for implementing Project L-045H includes several features which enhance the likelihood that the project will be successful in; 1) meeting negotiated effluent water quality criteria; 2) preserving ambient air quality; and 3) providing superior safety for operating personnel and the public at large. The sections below discuss the features applicable to each of those three categories.

### 10.3.1 Effluent Water Quality

Application of the BAT procedure has established that the combination of technologies incorporated in the proposed system is the best available at the present time. Regardless of the water quality criteria eventually established for Project L-045H, it is unlikely that effluent water quality could be improved significantly with any technology currently available, without substantial increases in both capital and operating costs.

### 10.3.2 Air Quality

The L-045H Project is primarily concerned with the treatment of liquid wastes emanating from various 300 Area facilities. In the selection of BAT, air emissions from the treatment units were considered in the selection of the treatment technologies. The selected technologies do not generate significant air emissions because they operate at ambient temperatures and pressures and do not require vigorous agitation to accomplish treatment goals.

10.3.3 Safety

Safety is an important element of the technology selection process for the L-045H project. For each treatment alternative considered, hazardous chemicals and safety hazards associated with the treatment process equipment have been identified. Identification of these concerns is appropriate during the technology selection phase so that unsafe processes can be eliminated from consideration and safety threats of the BAT can be attenuated during the detailed design phase. The selected BAT is a very safe process, operating under ambient temperature and pressure conditions with a minimum of moving parts and no known use of hazardous chemical additives.

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## 12.0 ACRONYMS

AKART -	All Known, Available, and Reasonable methods of prevention, control and Treatment
BAT -	Best Available Technology
BATEA -	Best Available Technology Economically Achievable
BMP -	Best Management Practices
CDR -	Conceptual Design Report
CERCLA -	Comprehensive Environmental Response, Compensation, and Liability Act
CWA -	Clean Water Act
DCG -	Derived Concentration Guide
DOE -	U.S. Department of Energy
Ecology -	Washington Department of Ecology
EPA -	U.S. Environmental Protection Agency
GAC -	Granular Activated Carbon
GPM -	Gallons Per Minute
IX -	Ion Exchange
KEH -	Kaiser Engineers Hanford Company
LDR -	Land Disposal Restricted
LLW -	Low-Level Waste
MGD -	Million Gallons per Day
NPDES -	National Pollutant Discharge Elimination System
PAC -	Powdered Activated Carbon
RCRA -	Resource Conservation and Recovery Act
RO -	Reverse Osmosis

SWDP - Washington State Waste Discharge Permit  
TCLP - Toxic Characterization Leaching Procedure  
TOC - Total Organic Carbon  
TWF - Toxic Weighting Factor  
WHC - Westinghouse Hanford Company  
WQC - Water Quality Criteria

APPENDIX A: DERIVATION OF COST FACTORS

Calculation of Cost Factors - From Kaiser CDR (WHC-SD-L045H-CDR-001)  
 Appendix B - Cost Estimate Summary, Pages B-2 and B-3

	WBS No.	COST	COST FACTOR
Process Equipment Costs:		\$2,291,182	
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(Assume WBS 327102 (\$2,841,476) includes process equipment, auxiliary equipment, installation, and instrumentation. These are subtracted out assuming the ratios of 100%, 5%, 10%, and 8% respectively.)			
	327102	\$2,841,476	
Process Equipment + auxiliary equipment - installation + instrumentation		\$2,818,154	
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Auxiliary Equipment:		\$114,559	0.05
Installation:		\$229,118	0.10
Diversion Basin:	321000	\$498,580	
(Process Piping)	322000	\$799,238	
	323000	\$163,252	
	324000	\$150,033	
	325000	\$213,922	
		<u>\$1,825,025</u>	0.80
Instrumentation:		\$183,295	0.08
Building:	327103	\$270,380	
	327202	\$85,337	
	327203	\$217,172	
		<u>\$572,889</u>	0.25
Facilities:	327101	\$256,861	
	327201	\$96,766	
		<u>\$353,627</u>	0.15