SGW-35663
Revision 0

Detailed Analysis of the Most Promising Alternatives to Using Granular Activated Carbon to Treat 200-ZP-1 Groundwater and 200-PW-1 Soil Vapor

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

United States Department of Energy
P.O. Box 550
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COC	contaminant of concern
cfm	cubic feet per minute
DOE	U.S. Department of Energy
Ecology	Washington State Department of Ecology
EPA	U.S. Environmental Protection Agency
ERA	expedited response action
FH	Fluor Hanford, Inc.
GAC	granular activated carbon
gpm	gallons per minute
HEPA	high-efficiency particulate air
NRC	U.S. Nuclear Regulatory Commission
O&M	operations and maintenance
OU	operable unit
ppm	parts per million
SVE	soil vapor extraction
VOC	volatile organic compound

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METRIC CONVERSION CHART

Into Metric Units		
If You Know	*Multiply By*	*To Get*
Length		
inches	25.4	millimeters
inches	2.54	centimeters
feet	0.305	meters
yards	0.914	meters
miles	1.609	kilometers
Area		
sq. inches	6.452	sq. centimeters
sq. feet	0.093	sq. meters
sq. yards	0.836	sq. meters
sq. miles	2.6	sq. kilometers
acres	0.405	hectares
Mass (weight)		
ounces	28.35	grams
pounds	0.454	kilograms
ton	0.907	metric ton
Volume		
teaspoons	5	milliliters
tablespoons	15	milliliters
fluid ounces	30	milliliters
cups	0.24	liters
pints	0.47	liters
quarts	0.95	liters
gallons	3.8	liters
cubic feet	0.028	cubic meters
cubic yards	0.765	cubic meters
Temperature		
Fahrenheit	subtract 32, then multiply by 5/9	Celsius
Radioactivity		
picocuries	37	millibecquerel

Out of Metric Units		
If You Know	*Multiply By*	*To Get*
Length		
millimeters	0.039	inches
centimeters	0.394	inches
meters	3.281	feet
meters	1.094	yards
kilometers	0.621	miles
Area		
sq. centimeters	0.155	sq. inches
sq. meters	10.76	sq. feet
sq. meters	1.196	sq. yards
sq. kilometers	0.4	sq. miles
hectares	2.47	acres
Mass (weight)		
grams	0.035	ounces
kilograms	2.205	pounds
metric ton	1.102	ton
Volume		
milliliters	0.033	fluid ounces
liters	2.1	pints
liters	1.057	quarts
liters	0.264	gallons
cubic meters	35.315	cubic feet
cubic meters	1.308	cubic yards
Temperature		
Celsius	multiply by 9/5, then add 32	Fahrenheit
Radioactivity		
millibecquerels	0.027	picocuries

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1.0 INTRODUCTION

This document presents a detailed evaluation of selected alternative treatment options to granular activated carbon (GAC) for removing carbon tetrachloride generated from the groundwater pump-and-treat system at the 200-ZP-1 Operable Unit (OU) in the 200 West Area of the Hanford Site. This evaluation of alternative treatment options to GAC is also applicable to the vadose zone soil vapor extraction (SVE) system at the 200-PW-1 OU, which is also located in the Hanford Site's 200 West Area.

1.1 BACKGROUND INFORMATION

The 200-ZP-1 OU is one of two groundwater OUs located within the 200 West groundwater aggregate area of the Hanford Site. The location of the 200-ZP-1 OU is shown in Figure 1-1. The 200-ZP-1 OU groundwater underlies Z Plant, T Plant, Low-Level Waste Management Areas 3 and 4, 241-T Tank Farm, 241-TX/TY Tank Farms, the State-Approved Land Disposal Site, and various cribs and trenches that formerly received liquid and solid waste as part of past waste disposal practices.

A pump-and-treat system for the 200-ZP-1 OU was implemented in 1995 in accordance with the *Declaration of the Interim Record of Decision for the 200-ZP-1 Operable Unit* (EPA et al. 1995). The groundwater pump-and-treat system is used to control the high-concentration portion of a carbon tetrachloride plume near the Plutonium Finishing Plant. This interim remedy is being implemented while groundwater characterization in support of the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* remedial investigation/ feasibility study process is being completed within the OU. Other volatile organic contaminants of concern (COCs) within the 200-ZP-1 OU being remediated using the pump-and-treat system (besides carbon tetrachloride) are chloroform and trichloroethylene.

Carbon tetrachloride and other volatile organic compounds (VOCs) are removed from groundwater through evaporative treatment (air stripping) and are then removed from the vapor stream using GAC (*Remedial Investigation Report for 200-ZP-1 Groundwater Operable Unit* [DOE/RL-2006-24]). A view of the 200-ZP-1 pump-and-treat facility is shown in Figure 1-2, and the GAC canisters inside the treatment building are shown in Figure 1-3. Figure 1-4 shows a facility plan of the 200-ZP-1 treatment building and equipment, and Figure 1-5 is a process flow diagram of the 200-ZP-1 pump-and-treat system.

The 200-PW-1 OU waste sites that overlie the 200-ZP-1 groundwater received plutonium/ organic-rich liquid waste from Z Plant. Carbon tetrachloride was discharged primarily to three waste sites from 1955 through 1973: the 216-Z-9 Trench, the 216-Z-1A tile field, and the 216-Z-18 Crib. The SVE systems began operation in 1992 as an expedited response action (ERA) to extract carbon tetrachloride from the vadose zone in the 200-PW-1 OU (formerly designated as the 200-ZP-2 OU). The objective of the ERA, as stated in the *Action Memorandum: Expedited Response Action Proposal for 200 West Area Carbon Tetrachloride Plume* issued in January 1992 by the U.S. Environmental Protection Agency (EPA) and the Washington State Department of Ecology (Ecology) (EPA and Ecology 1992) is to mitigate the threat to site workers, public health, and the environment caused by the migration of carbon tetrachloride vapors through the soil column and into the groundwater. The ERA is an interim

action taken to reduce the mass of carbon tetrachloride in the soil column beneath the 200 West Area pending final cleanup activities.

The 200-PW-1 SVE system includes GAC canisters to remove carbon tetrachloride from the extracted vapors prior to discharge (*Performance Evaluation Report for Soil Vapor Extraction Operations at 200-PW-1 Carbon Tetrachloride Site FY2005* [WMP-30426]). Figures 1-6 and 1-7, respectively, show the 200-PW-1 SVE system and the GAC canisters.

The scope of this evaluation of alternative treatment options to GAC was limited to the 200-ZP-1 OU, but the alternative treatment options evaluated here (with the exception of the groundwater treatment alternatives) would also be applicable for use at the 200-PW-1 OU.

Until recently, the GAC canisters for the 200-ZP-1 and 200-PW-1 systems were shipped offsite for regeneration when they became loaded with carbon tetrachloride. The GAC was sent to a regeneration facility located in Parker, Arizona, which is operated by U.S. Filter Corporation, a subsidiary of Siemens Water Technologies Corporation. Fluor Hanford, Inc. (FH) had been sending spent GAC vessels for offsite regeneration at the rate of approximately 26 vessels/year. However, recent detections of trace levels of radiation in the GAC canisters prompted the regeneration facility to temporarily stop accepting the canisters from FH for regeneration. As a result, other options needed to be evaluated for removing carbon tetrachloride from air coming from the 200-ZP-1 OU stripping tower and the 200-PW-1 OU SVE system. A preliminary evaluation of several treatment alternatives was conducted from which four alternatives were recommended for further assessment to determine effectiveness, implementability, cost, and other relevant factors.

In August 2007, during the final evaluation of recommended alternatives, the U.S. Department of Energy (DOE) received authorization from the U.S. Nuclear Regulatory Commission (NRC) to once again transport spent GAC from the 200-ZP-1 and 200-PW-1 systems for offsite regeneration at the facility in Parker, Arizona. Nevertheless, this evaluation of alternative treatment options to GAC was completed and may be useful for future reference if shipping the GAC to an offsite regeneration facility were again prohibited for some reason or for consideration of potential treatment technologies to be incorporated into the final site remedial action.

1.2 RADIOLOGICAL CONTAMINANTS

The radiological contaminants were described in a document that evaluated the potential levels of exposure, which was submitted to the NRC to seek approval for continued offsite regeneration of the GAC (*Authorized Limit Request for the Regeneration of Granular Activated Carbon at the 200-ZP-1 and 200-PW-2 Pump-and-Treat Operations* [FH-0602994.1]). A summary of the discussion of radiological contaminants in that document is provided in this section.

Prior to construction of the carbon tetrachloride SVE system, a study was performed to determine the potential for the GAC to become radiologically contaminated. The study concluded the following: "There is little chance of outside transport, via vapor extraction, of Pu-239, Pu-240, and Am-241 in the volatile state or associated with particulates" (IM 81223-91-003). This has been the basis for the design and operation of the 200-PW-1 and 200-ZP-1 OU facilities (*Expedited Response Action Proposal (EE/CA & EA) for 200 West Area Carbon Tetrachloride Plume* [DOE/RL-91-32]).

In addition to the potential radiological contaminants introduced to the GAC from the SVE and pump-and-treat operations, the background contamination of the GAC (either as new or regenerated GAC) is also a consideration. Analysis results from a few samples of new and regenerated GAC indicate detectable levels of uranium and thorium.

The radiological contaminants, the maximum results from samples of loaded GAC, and background (i.e., baseline) GAC radiological testing results are presented in Table 1-1. As indicated in Table 1-1, the detected uranium and thorium-232 in background (i.e., unused) GAC samples were 60% to 80% of the maximum sample results from the used GAC samples.

Figure 1-1. Location of 200 West Area and the 200-ZP-1 Operable Unit.

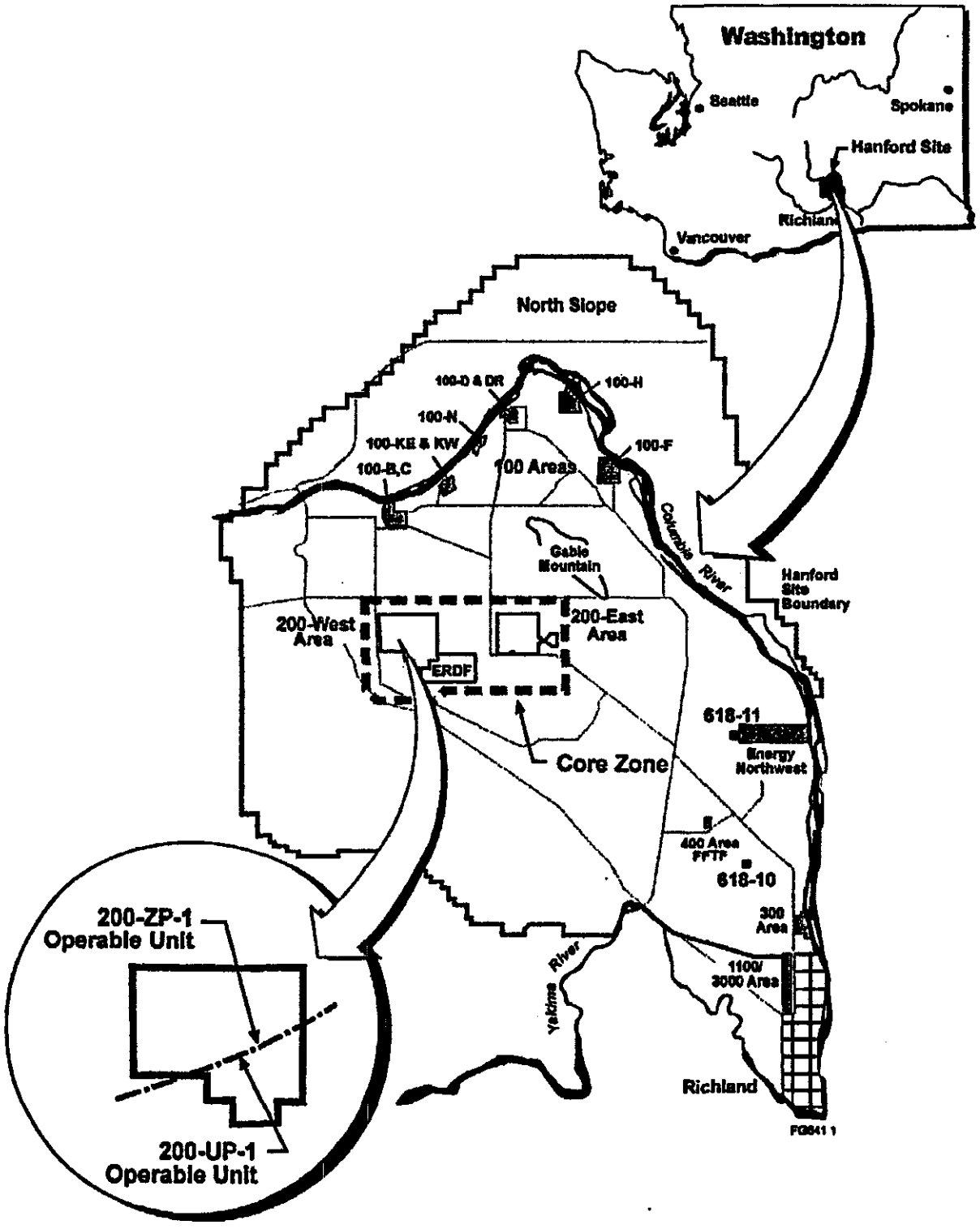

Figure 1-2. External View of 200-ZP-1 Facility.

Figure 1-3. 200-ZP-1 Granular Activated Carbon Canisters (Total of Six Canisters).

Figure 1-4. Existing Pump-and-Treat system, 200-ZP-1 Site Plan.

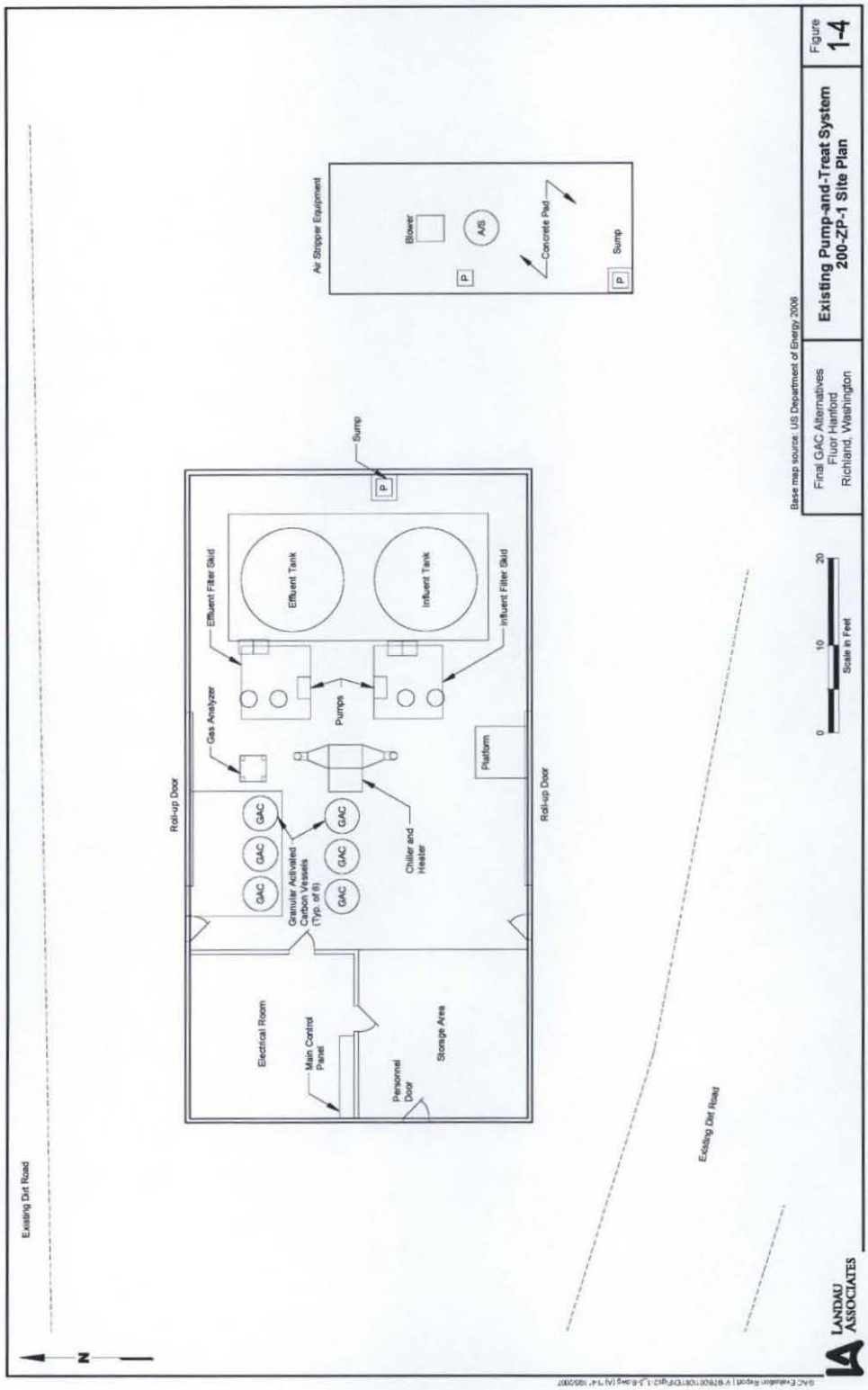

Figure 1-5. Existing Pump-and-Treat System, 200-ZP-1 Process Flow Diagram.

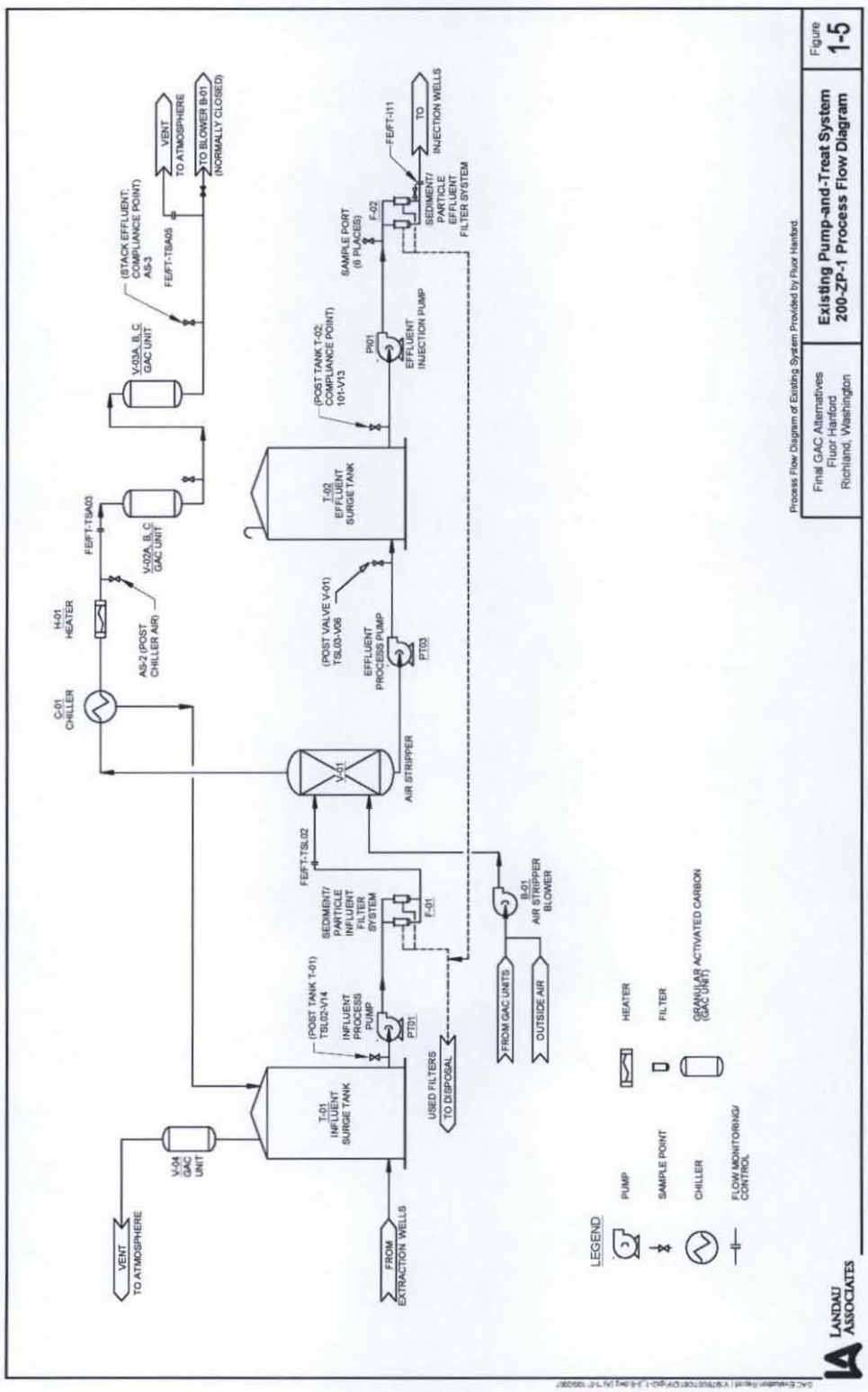

Figure 1-6. 200-PW-1 Soil Vapor Extraction System.

Figure 1-7. 200-PW-1 Granular Activated Carbon Canisters (Two Used in Series).

Table 1-1. Radiological Contaminants of Concern, Maximum Granular Activated Carbon Sample Results, and Background Granular Activated Carbon Radioactivity.

200-ZP-1[a]	200-PW-1[a]	Maximum Sample Results (pCi/g)	Background Activity (pCi/g)
	Am-241	ND (1)[e]	---
C-14	C-14	ND (50)[e]	---
Cs-137	Cs-137	ND (1)[e]	ND (0.02)[e]
	Co-60	ND (1)[e]	---
	Europium isotopes (Eu-152, -154, -155)	ND (1)[e]	---
I-129	I-129	ND (2)[e]	---
Np-237	Np-237	**0.065**	---
	Plutonium isotopes (Pu-238, -239, -240)	**0.003 (Pu-238), 0.081 (Pu-239/240)**	---
Pa-231		**0.356**	---
Se-79[b]		ND (10)[e]	---
Sr-90	Sr-90	ND (10)[e]	---
Tc-99	Tc-99	ND (15)[e]	---
	Th-232[c]	**0.372**	**0.239**[f]
	Th-230	---	ND (0.2)[e]
	Th-228	---	**0.219**
	Pb-210	---	ND (0.4)[e]
H-3	H-3	**127.0**	---
Uranium, total (U-238, -235, and -234)[d]	Uranium, total (U-238, -235, and -234)[d]	**0.641 mg/kg**	**0.504 mg/kg**
Gross alpha		---	ND (2.4)[e]
Gross beta		---	ND (4)[e]

[a] Obtained from *Sampling and Analysis Instruction for Characterization of 200-ZP-1 and 200-ZP-1 Spent Granulated Activated Carbon and Filter Elements* (DOE/RL-2006-54), Table 1-2 for 200-ZP-1 and Table 1-4 for 200-PW-1.

[b] Se-79 is difficult to analyze. If Cs-137 is detected, Se-79 concentrations will conservatively be assumed to be the same.

[c] Progeny included in the analysis.

[d] Short-lived progeny included in the analysis.

[e] Parameter not detected, value listed is the Reporting Limit value from DOE/RL-2006-54.

[f] Average of three samples.

ND = parameter not detected

--- = not tested or data not available

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2.0 IDENTIFICATION OF ALTERNATIVE TREATMENT OPTIONS

A preliminary evaluation of alternative treatment options to GAC was previously prepared for use at the 200-ZP-1 pump-and-treat system (SGW-34467). The treatment alternatives that were considered also generally applied to the SVE operations at the 200-PW-1 OU.

Based on the results of the preliminary evaluation, a number of the initially identified alternative treatment options were deemed to be unsuitable for continued evaluation on the basis of effectiveness, implementability, and/or cost. The alternative treatment options that were recommended to be evaluated in greater detail for potential use at the 200-ZP-1 pump-and-treat system and the 200-PW-1 SVE system are listed below:

- Use of a high-efficiency particulate air (HEPA) filter on the vapor stream prior to GAC
- Use of a second or larger chiller/condenser on the vapor stream prior to GAC
- Onsite steam regeneration of vapor-phase GAC
- Replacement of the GAC vessels with a catalytic oxidizer.

Detailed evaluations of each of these selected alternative treatment options are discussed in the Section 3.0.

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3.0 EVALUATION OF ALTERNATIVE TREATMENT OPTIONS

The alternative treatment options to using GAC identified in Section 2.0 were previously evaluated with respect to the criteria of effectiveness, technical implementability, administrative implementability, potential exposure of workers to radioactivity, estimated capital cost, and estimated operating costs. In addition to the preliminary evaluation criteria, the alternative treatment options discussed here are further evaluated in more detail with respect to those evaluation criteria and are also evaluated to determine modifications that may be required to the current system and controls, modifications to operation and maintenance procedures, wastes generated and potential releases to air, and technical life expectancy.

As a basis for comparing the alternative treatment options, the pump-and-treat system operational conditions were used based on recent system operation. The assumed operational parameters are as follows:

- Average groundwater extraction flow rate = 270 gallons per minute (gpm)
- Average influent carbon tetrachloride concentration in groundwater = 1,600 micrograms per liter (µg/L)
- Air (vapor) flow rate through the air stripper = 800 cubic feet per minute (cfm).

Descriptions of the identified recommended treatment alternatives with respect to the evaluation criteria are provided in the following subsections. All four alternatives would continue to use the air stripper for groundwater treatment. The first three alternatives summarized below (use of a HEPA filter, use of a second or larger chiller, and onsite steam regeneration of GAC) would also continue to use vapor-phase GAC for adsorption of VOCs. The fourth alternative would replace GAC with a catalytic oxidizer for thermal destruction of the VOCs.

For ease of discussion, these four alternative technologies are described as being implemented for the 200-ZP-1 groundwater treatment system; however, these four alternatives are equally implementable on the 200-PW-1 SVE operations. The specific estimated costs for implementing these technologies will be different for 200-PW-1 versus 200-ZP-1, but the relative costs of the four technologies are expected to be roughly the same.

3.1 INSTALLATION OF A HIGH-EFFICIENCY PARTICULATE AIR FILTER PRIOR TO GRANULAR ACTIVATED CARBON

Adding a HEPA filter to the air stream from the air stripper would be employed to remove small particulates, including submicron particles from vapors exiting the air stripper. This filtration would be expected to enhance the removal of radioactive material from the vapor stream and may prevent radioactivity from passing through to the GAC vessels. It should be noted that the term "HEPA" is used in this document to imply general particulate removal from an air stream, and the term, as used here, should not be taken to imply a specific set of regulatory performance standards that may be associated with certain industrial applications or for personal health and safety equipment applications.

A site facility plan showing the proposed layout of equipment for this alternative is shown in Figure 3-1. A process flow diagram of this alternative is shown in Figure 3-2.

3.1.1 General Technology Evaluation

The existing chiller and heater units (or new chiller and heater units) would still be employed to reduce the relative humidity of the vapor stream for enhanced VOC removal efficiency by the GAC and to prevent the HEPA filters from getting wet, which could negatively affect the filtration effectiveness. HEPA filters are commonly used in the nuclear power industry for removing radioactive particulates. The nuclear-grade HEPA filters meet various specifications, including the *Code on Nuclear Air and Gas Treatment* (ANSI/ASME AG-1), IEST-RP-CC001.4 Type B (*Handbook of Air Filtration* [IEST 1997]), MIL-STD-282 (*Military Standard Filter Units, Protective Clothing, Gas Mask Components, and Related Products: Performance Test Method*), and the DOE standard *Specification for HEPA Filters Used by DOE Contractors* (DOE-STD-3020-2005). HEPA filters are highly effective at removing particles less than 0.3 microns in size, and commercially available sizes can accommodate flows up to 2,000 cfm. Because testing data on the concentration of particulates and radioactivity in the vapor stream have not been collected, it cannot be determined whether this alternative would be capable of eliminating all sources of radioactivity to the GAC to below detection limits or to below background levels in GAC. There is concern, especially for tritium with its small radius of less than a nanometer, that unless it is complexed with a much larger molecule or sorbed onto particulates, it would not be removed with HEPA filtration and that the HEPA filter would not prevent loading onto the GAC to below detection limits.

Implementing HEPA filtration can be readily achieved due to ease of availability and relatively low cost. As with installation of a larger chiller, this alternative is expected to have favorable administrative implementability relative to other alternatives because it does not alter the general design basis of the existing treatment system. The filters would need to be replaced periodically, so to the degree at which the HEPA filter elements remove radioactive particulates there would be some increase in exposure to system operation and maintenance personnel.

The following subsections provide additional detail related to other evaluation criteria.

3.1.2 Required Modifications to the Existing Treatment System

Two HEPA filter housings would be installed on the vapor conveyance line downstream from the existing chiller and heater equipment. Piping between the heater and the existing GAC vessels would be modified to accommodate the filter housings. The two filters would be installed in parallel, so the conveyance piping would be installed with a tee so the air flow is split between the two filters.

Based on information supplied by a HEPA filter manufacturer, a filter housing that would accommodate an airflow rate of approximately 1,000 cfm would have dimensions of approximately 27 in. wide by 30 in. high by 38 in. deep. The HEPA filter elements would have approximate dimensions of 24 in. by 24 in. by 12 in. deep. Isolation dampers or valves would be installed in the ducting upstream and downstream of the filters to allow for filter maintenance or replacement while the system continues to operate. The overall length of the filter housings with the ductwork transitions and isolation valves at each end is estimated to be approximately 60 in. The housings could be placed near the existing GAC vessels in the available area within the treatment building.

The filter housings would have side access doors for accessing the filters for replacement or maintenance and can be equipped with differential pressure gauges, as well as static pressure taps for installation of pressure gauges. At least 3 ft of space should be available next to the side access doors to allow enough room for accessing the filters.

3.1.3 Required Modifications to Existing System Controls

Modifications to the control system and the addition of an alarm for high differential pressure would be optional. A high differential pressure alarm would alert the operator that the HEPA filter elements need to be replaced with new filters. However, control system modification is not considered to be necessary for implementing the HEPA filters. Specific data has not been collected for the concentration of particulates in the vapor stream exiting the air stripper, but the concentration is expected to be relatively low. Based on similar types of applications, it is estimated that the HEPA filters may only need to be replaced on an annual frequency. However, for cost-estimating purposes, the replacement frequency is estimated to be once per month. Inlet and outlet pressure or differential pressure at the filter housings can be monitored manually on a daily or weekly basis to determine when filter replacement is required, without the need for an automatic system alarm.

3.1.4 Required Modifications to System Operation and Maintenance

Replacement of HEPA filters may be required as often as once per month and would require a few hours of an operator's time to replace both filters and to coordinate disposal. Examination of differential pressure across the filters would need to be added to the system's routine daily or weekly monitoring program.

With the August 2007 acceptance by NRC of continued offsite regeneration of GAC, there is no longer immediate concern or need to test the spent GAC for radioactivity. However, it is assumed that if there would be enough concern about the spent GAC in the future where HEPA filtration would be required, then there would also be some level of testing the effectiveness of the air filtration. For purposes of a cost estimate and technology comparison, it is assumed that there would be quarterly HEPA effluent air testing (or possible testing of the spent GAC) to perform a limited analysis of radioactive indicator compounds.

3.1.5 Wastes Generated

The spent HEPA filter elements would require disposal, but the filters would not be expected to retain detectable levels of VOCs and could be disposed at the Environmental Restoration Disposal Facility at the Hanford Site without concern of exceeding the 6 mg/kg land disposal restriction for carbon tetrachloride.

3.1.6 Potential Releases to Air

The only expected change to air emissions is the small volume of air from the air-stripper effluent stream that would be released during each HEPA filter replacement event. The isolation valves on the filter housing would limit the volume of untreated air that is released to no more than a few liters per filter replacement.

3.1.7 Life Expectancy of Technology

The HEPA filter housings would be expected to have a service life of at least 10 years before requiring replacement. A high-humidity environment could reduce the life of the housing, but it is estimated that the HEPA filters would be placed downstream of the chiller/condenser and the heater and would, therefore, be in a low-humidity environment.

3.1.8 Estimated Capital and Annual Operating Costs

The capital cost of implementing HEPA filtration at the 200-ZP-1 OU is estimated to be approximately $68,000, and the annual operating cost is estimated to be approximately $40,000. The present-value cost of this alternative for 10 years of system operation is estimated to be approximately $460,000. A 4% discount factor was used in the evaluation to estimate the present value of future costs, and a 20% contingency was added to the total estimated costs. The details of this cost estimate are provided in Table 3-1.

3.2 INSTALLATION OF A LARGER CHILLER/CONDENSER PRIOR TO GRANULAR ACTIVATED CARBON

The existing chiller/condenser and heater for the vapor stream exiting the air stripper are designed to cool the vapor stream, condense and remove entrained water droplets and water vapor, and then reheat the vapor to a low relative humidity. A plan view of this equipment layout and a process flow diagram are shown in Figures 1-4 and 1-5, respectively. The existing system typically reduces the relative humidity to below approximately 30%. The purpose of achieving a low relative humidity in the air stream is because GAC is significantly more effective in the removal of VOCs at low relative humidity compared to high relative humidity. This reduced adsorption efficiency at higher relative humidity is caused by the collection of moisture in the pores of the activated carbon.

With the exception of tritium, the radioactive elements listed in Table 1-1 are not considered to be volatile compounds that would transfer from groundwater into the vapor phase, thus it was not expected during initial treatment system design that the GAC would be impacted by radioactivity. However, it may be that particles in small water droplets or water vapor are carrying radioactivity and are being entrained in the air-stripper vapor stream, are not being removed in the existing chiller/condenser, and are depositing onto the GAC. Within the past year, problems were observed with the operation of the existing chiller. When the existing chiller is not functioning properly, water droplets and water vapors from the air stripper may pass through the chiller and become deposited onto the GAC.

A desiccant system would be a possible option for reducing the relative humidity. However, the chlorinated VOCs would also potentially adsorb to the desiccant and would complicate the heating and atmospheric venting of the collected water vapor. Therefore, use of a desiccant at the Hanford Site is not considered further.

Installation of a second chiller/condenser in series with the existing chiller would be a possible option. However, based on discussions with site operators regarding the reliability of this unit and because the chiller and heater are inside one packaged unit, replacement of the existing chiller and heater unit with a larger, more efficient chiller and a new heater appears to be a preferable option and is, therefore, the focus of assessment for this alternative. A site facility plan showing the proposed layout of equipment for this alternative is shown in Figure 3-3. A process flow diagram of this alternative is provided in Figure 3-4.

3.2.1 General Technology Evaluation

Replacing the existing chiller with a larger, more efficient chiller would improve separation of water from the vapor stream exiting the air stripper. Enhanced removal of water droplets and reduction of humidity that potentially contain radioactive material would help to prevent radioactivity from passing through to the GAC vessels. Implementing a larger chiller would be a viable option, as sufficient space within the treatment system building is expected to be available and costs are expected to be relatively low to moderate. This alternative may have greater administrative implementability relative to other alternatives because it does not alter the general design basis of the initial treatment system. However, it cannot be determined with available information whether this alternative would be capable of eliminating sources of radioactivity to the GAC to below detection limits, or to below background concentrations. A chiller/condenser system cannot practically remove 100% of the water vapor.

The following subsections provide more detail related to other evaluation criteria.

3.2.2 Required Modifications to Existing Treatment System

A larger chiller/condenser and new heater would likely require a slightly larger floor space and would require minor modification to the ducting. The larger chiller/condenser would have a larger electrical power draw and, thereby, would require some electrical supply modifications.

3.2.3 Required Modifications to Existing System Controls

Because this alternative would be an improvement of an existing set of equipment, extensive control system modifications would not be required. To minimize the need for modifications to the existing main control system, the new chiller and heater system could be provided with its own control panel to allow monitoring of the operation and to provide warning alarms. It would be recommended to add a control interlock from the new chiller and heater system control panel to the main treatment system control panel to activate an alarm and shut the treatment system down in the unlikely event of a failure of the chiller/condenser system.

3.2.4 Required Modifications to System Operation and Maintenance

No significant modifications to system operation and maintenance would be required with the installation of a larger chiller/condenser unit.

Similar to HEPA filtration described above, it is assumed that if there would again be heightened concern in the future about radioactivity on the spent GAC, then sampling would be performed to periodically test the effectiveness of the larger chiller/condenser unit in removing those COCs. For purposes of a cost estimate and technology comparison, it is assumed that there would be quarterly chiller/condenser effluent air testing (or possible testing of the spent GAC) to perform a limited analysis of radioactive indicator compounds.

3.2.5 Wastes Generated

An increased volume of condensed water would be generated by the larger chiller/condenser. However, the condensed water would be pumped to the influent groundwater stream for treatment through the air stripper, as is the current process for handling the condensed water. No new waste stream would be generated.

3.2.6 Potential Releases to Air

The larger chiller/condenser system would still be part of the same closed ducting system for vapor treatment and would continue to use vapor-phase GAC for removal of VOCs. No increase in air emissions would be expected. The larger chiller/condenser would be installed with the objective to eliminate entrained water droplets and significantly reduce water vapor in order to reduce or eliminate traces of radioactive compounds from passing through from the air stripper to the GAC.

3.2.7 Life Expectancy of Technology

The warranty provided for the larger chiller/condenser unit would depend on which equipment manufacturer is selected, but the warranty would cover at least 1 year of operation. With continuous operation, the equipment life is estimated to be approximately 10 years.

3.2.8 Estimated Capital and Annual Operating Costs

The capital cost of installing a larger chiller/condenser system at the 200-ZP-1 OU is estimated to be approximately $150,000, and the annual operating cost is estimated to be approximately $42,000. The present-value cost of this alternative for 10 years of system operation is estimated to be approximately $560,000. The details of this cost estimate are provided in Table 3-2.

3.3 ONSITE REGENERATION OF SPENT GRANULAR ACTIVATED CARBON USING STEAM

The regeneration of spent GAC onsite using steam would eliminate the need to ship the material offsite for regeneration. For this treatment option, an automatic batch process would be employed to isolate a spent GAC vessel and desorb the accumulated VOCs using steam. A new boiler would need to be installed onsite to produce the steam. Regenerative carbon adsorption systems use multiple vessels for switching between adsorption and regeneration modes. A site facility plan showing the proposed layout of equipment for this alternative is shown in Figure 3-5, and a process flow diagram of this alternative is shown in Figure 3-6.

3.3.1 General Technology Evaluation

Steam regeneration is expected to be effective in removing carbon tetrachloride and other VOCs from the spent GAC to allow for continued reuse in the system for many years. There is a fairly high confidence in the performance of this technology because it has been implemented at other full-scale groundwater pump-and-treat systems. A steam regeneration system could be installed at the site in less than 6 months from the time that a system was ordered from a supplier. The use of steam-regenerated GAC would still be expected to achieve nondetect concentrations of VOCs in the air emissions, but because this process would be a change in the treatment system design, it is expected that lead agency and lead regulatory agency approval would be needed prior to implementation. This alternative would not increase the exposure of workers to the GAC because the steam regeneration process occurs within the GAC vessels without the need for physical transfer. However, occasional handling of drums containing the concentrated carbon tetrachloride liquid would be necessary.

It was previously estimated that the space required to implement this alternative would need to accommodate four GAC adsorption/regeneration vessels on two equipment skids approximately 8-ft wide by 12-ft long by 12-ft high and include enough space for the boiler and liquid

collection tanks. However, evaluation of the current VOC loading rate and communication with vendors of steam regeneration equipment regarding time necessary for steam regeneration cycles indicate that only two vessels with approximately 2,000 lb each of GAC would be necessary for this alternative. These two GAC vessels could be provided on one 8-ft by 12-ft skid.

As shown in Figures 3-5 and 3-6, the two GAC vessels could be placed in parallel operation, with one GAC vessel operating while the other is off-line. Operation with one GAC vessel versus the current six GAC vessels appears at first examination to offer less of a safety factor for breakthrough of VOCs. However, with onsite steam regeneration of a GAC vessel performed each day, there is a built-in safety factor of regenerating the GAC well before the time at which breakthrough of VOCs would occur.

If an added level of conservatism related to GAC breakthrough is still desired, then the two GAC vessels could also be placed in series operation. Considering that a steam regeneration cycle would only require a 2- to 3-hour period, the GAC vessels could be operated in series for 21 to 22 hours/day. There would be a modest added cost for additional automated valves to control the alternation of lead and lag GAC vessels.

3.3.2 Required Modifications to Existing Treatment System

To implement a regenerative carbon adsorption system, the six existing GAC vessels would need to be disconnected and removed from the treatment building. An 8-ft by 12-ft skid containing two regenerative GAC vessels and associated equipment would be placed within the treatment building in the area that the six existing GAC vessels currently occupy. The regenerative GAC vessels would be approximately 42 in. in diameter and 72 in. in height. Other equipment on the skid would include a drying cycle blower, a condenser, a condensate cooler, a decanter for separating solvent from water, and all associated control valves, sensors, and switches. These components would require appropriate plumbing, mechanical, and electrical connections per the vendor-supplied installation manual.

Vapor influent piping to the GAC vessels is currently split into three parallel vapor streams and would need to be modified down to two parallel vapor streams, one each connected to a regenerative GAC vessel. Control valves at each GAC vessel would be set so one of the GAC vessels operates in adsorption mode while the other is off-line for regeneration mode. Influent and effluent sensors and pressure gauges installed at each GAC vessel would continuously monitor vapor flows and concentrations, as well as pressure drop through each vessel, during operation. When breakthrough is detected at the adsorbing GAC vessel, the system will automatically switch the control valves between operational modes, thereby activating regeneration mode for the spent GAC and activating adsorption mode for the other GAC vessel.

An electric boiler capable of delivering approximately 120 lb/hour of steam for the regeneration process would be installed separately, either inside the treatment building or outside (*Ballpark Study for 800 SCFM Steam Regenerable Carbon Bed System AMCEC A3081* [AMCEC 2007]). The space required to accommodate an appropriately sized boiler is estimated to be at least 8 ft by 10 ft. The boiler would require three-phase, 480V, 650 amp electrical service to operate. A clean source of feed water should also be available for providing 4 gpm makeup water for steam generation. Piping would be installed from the boiler to each of the GAC vessels for conveyance of pressurized steam.

A solvent collection drum (over-packed 55-gal steel) would be installed near the main equipment skid and plumbed for gravity feed of solvent from the decanter. Wastewater conveyance piping would also be installed from the decanter to the treatment system's influent surge tank for reprocessing of the water from the regeneration process (i.e., treatment through the existing air stripper).

3.3.3 Required Modifications to Existing System Controls

Existing controls would not require significant modification since the regenerative GAC system would include a separate control panel with all associated controls necessary for automatic operation. The panel could be installed in a nonhazardous location within the treatment building or outside. A communication line would be installed from the new control panel to the system control room to activate shutdown of the treatment system in the unlikely event of a failure alarm condition associated with the regenerative carbon equipment (i.e., detection of VOCs in the effluent stream of one GAC vessel when the other GAC vessel has not yet completed its steam regeneration cycle and is not available for use).

3.3.4 Required Modifications to System Operation and Maintenance

Implementation of a regenerative carbon system will eliminate the need to replace the GAC vessels (at a current rate of approximately 26 per year). Because the system would operate continuously through use of automatic controls, very little hands-on operation would be required for handling the equipment or the GAC. Standard monitoring of system operational conditions (i.e., pressures, temperatures, flows, concentrations, etc.) would still be required to monitor overall operation.

Handling of drums containing condensed solvents recovered from the GAC regeneration process would be added to normal system operation and maintenance procedures. Because there would not be the need for offsite regeneration of the GAC with this alternative, it is assumed that periodic testing of air samples or spent GAC for radioactivity would not be needed.

3.3.5 Wastes Generated

Steam regeneration of the GAC would produce concentrated carbon tetrachloride liquid and also wastewater containing some dissolved constituents. The wastewater would be pumped back to the air stripper for treatment, and the liquid carbon tetrachloride would be collected and stored in drums prior to offsite recycling or incineration.

Based on influent flow rate and VOC concentrations, it is expected that the GAC regeneration and VOC recovery process would produce approximately one 55-gal drum of condensed VOCs (primarily carbon tetrachloride) every 3 to 4 months. As such, procedures would include measuring product level in the collection drum at least once per month and coordinating periodic offsite transport of the recovered carbon tetrachloride liquid a few times per year. The drums containing recovered carbon tetrachloride would be transported offsite either for solvent recycling (if an appropriate user could be identified), or more likely for incineration. It is expected, although no data are available for confirmation, that there would not be levels of radioactivity in the recovered carbon tetrachloride that would prevent offsite recycling or incineration. Furthermore, it is expected that the recovered carbon tetrachloride could be pumped through a submicron filter, if necessary, to remove any particulates that are the source of the radioactivity.

It would be recommended, prior to selection and implementation of onsite GAC regeneration, to perform VOC recovery testing and to test for radioactivity in the recovered VOCs. That testing could help to confirm whether the recovered liquid VOCs meet all necessary criteria for offsite transport and incineration.

3.3.6 Potential Releases to Air

Use of regenerative GAC would effectively adsorb the VOCs in the vapor stream, and data from previous similar full-scale applications have shown that this type of system is capable of achieving nondetectable concentrations in air emissions. Additionally, through the use of automatic sensors and controls, the GAC vessels will switch between adsorption and regeneration modes at the instant that breakthrough would be detected. Secondary sensors could also be installed for added safety if the primary sensors were to malfunction. Installing secondary sensors would be more cost effective than installing a second skid with additional GAC vessels.

3.3.7 Life Expectancy of Technology

Regenerative GAC used in systems at other sites for similar applications has proven to work effectively for periods of over 10 years. It is expected that this technology could be used at the site for as many as 20 years before the GAC would reach a level of inefficient adsorption capacity. However, the overall lifespan could be less and can vary depending on several factors. For instance, fouling of the GAC caused by scale buildup from the steam water supply could potentially occur, which would result in a shorter life span. Therefore, it is recommended that the feed water source for the boiler be of good quality with low solids concentration and relatively free of calcium and magnesium (i.e., minerals that are the source of water hardness).

3.3.8 Estimated Capital and Annual Operating Costs

Multiple companies will design and produce onsite steam GAC regeneration systems. A facility using a system produced by AMCEC, Inc. was recently visited, and for the 50-gpm system, the cost of the air stripper, two GAC canisters, and steam regeneration equipment was estimated at approximately $700,000 (*Onsite Regeneration Site Visit Report: Portsmouth, Ohio Enrichment Plant, Piketon, Ohio* [FH 2007b]). The system that would be required for the 200-ZP-1 OU would be larger but would not require a new air stripper. The capital cost of implementing onsite steam regeneration at the 200-ZP-1 OU is estimated to be approximately $800,000, and the annual operating cost is estimated to be approximately $48,000. The present-value cost of this alternative for 10 years of system operation is estimated to be approximately $1,300,000. The details of this cost estimate are provided in Table 3-3.

3.4 CATALYTIC OXIDATION

With the catalytic oxidation treatment alternative, the VOCs in the vapor from the air stripper would be destroyed by reaction with oxygen at high temperature. Catalytic oxidizers use a catalyst for the oxidation reaction to occur at a lower temperature (approximately 900°F for carbon tetrachloride or other chlorinated VOCs) versus thermal oxidation. Due to the significant savings in fuel or electrical power costs, a catalytic oxidizer would be preferable to a thermal oxidizer. A site facility plan showing the proposed layout of equipment for this alternative is shown in Figure 3-7 and a process flow diagram of this alternative is shown in Figure 3-8.

3.4.1 General Technology Evaluation

The destruction efficiency for carbon tetrachloride and other VOCs is typically very high (greater than 98% or 99%) with the selection of the correct-size unit for the application. Oxidation of chlorinated VOCs (e.g., carbon tetrachloride) generates acid gases (HCl), so the oxidation system would need to be provided with a gas scrubber system. The scrubber would consist of spraying a water stream (in this case, treated groundwater) through the oxidized vapor stream to absorb the acid gas. The water used for scrubbing then may need to be pH-adjusted using a small amount of caustic prior to discharge. For most applications, the oxidizer would use a fuel source such as natural gas or propane to heat the catalyst beds; however, natural gas is not available in the vicinity of the 200-ZP-1 treatment building and the use of propane tanks at this location is prohibited due to its proximity to the former Plutonium Finishing Plant and explosion risk. Therefore, the catalytic oxidizer would need to be heated through the use of electric-powered heating elements.

Catalytic oxidation has been well demonstrated at the full-scale level, multiple vendors of the technology are available, and standard pre-packaged systems are available of the size that would be necessary for the 200-ZP-1 system.

3.4.2 Required Modifications to Existing Treatment System

To implement a catalytic oxidizer system for vapor treatment, the six existing GAC vessels would be disconnected and removed from the treatment building. All catalytic oxidizer and scrubber equipment could be installed within the treatment building in the area that currently contains the existing GAC units. The catalytic oxidizer equipment and associated piping, sensors, and control panel would be mounted on a skid approximately 5-ft wide by 13-ft long. The skid-mounted oxidizer equipment would be approximately 7-ft high. The scrubber equipment would include a sump, a quench tube, a scrubber stack, and all associated piping, sensors, and control valves and would be mounted on a skid approximately 5-ft wide and 7-ft long. The top of the quench tube would be approximately 8 ft above the floor, and the top of the scrubber stack would be approximately 10 ft above the floor. Effluent piping would extend from the scrubber stack and would need to transition through the building roof to discharge treated air to the outside.

Ducting would be installed for transfer of effluent vapors from the discharge port of the catalytic oxidizer to the influent port of the quench tube. A makeup water feed line would be connected to the quench tube with a control valve to adjust the flow to approximately 33 gpm.[1] The makeup water for the scrubber system could either be piped from the treated system effluent tank or from a potable water source. Water from the quench tube would collect in the scrubber sump, which would then be recycled back to the quench tube through recirculation piping via a recycle pump.

A caustic supply tank (30- to 50-gal capacity) would be installed near the scrubber skid. A small feed pump and tubing would be installed between the caustic supply tank and the scrubber stack to supply an estimated 0.07 gal/hour of 25% sodium hydroxide solution to the scrubber to neutralize acidic vapors from the catalytic oxidizer. Approximately 5% to 10% of the chloride will convert to chlorine gas. Scrubbing the chlorine gas requires that a reducing agent, such as

[1] This information was obtained via personal communication between Keith Herbert of Catalytic Combustion Corporation and Tena Seeds of Landau Associates, dated September 27, 2007.

sodium thiosulfate, be added to the caustic. The concentration of the reducing agent should be approximately 10% by weight (AMCEC 2007).

Implementation of the catalytic oxidizer and scrubber equipment would require three-phase, 480V electrical service to operate. The total electrical current requirement to run all of the equipment and to heat the catalyst beds to the minimum 900°F is estimated to be approximately 330 amps. The electrical power that would be required for the pre-heater and oxidizer is estimated to be approximately 260 kW.

The catalytic oxidizer unit would be insulated, but the system would still likely be a source of heat to the building. It is possible that a new or larger air conditioner would be required to maintain a comfortable temperature in the building in summer months.

3.4.3 Required Modifications to Existing System Controls

Existing controls would not require significant modification since the catalytic oxidizer and scrubber equipment would include a separate control panel with all associated controls necessary for automatic operation. The panel would be mounted on the catalytic oxidizer equipment skid. A communication line would be installed from the catalytic oxidizer control panel to the system control room to activate shutdown of the treatment system in the unlikely event of a failure alarm condition associated with the catalytic oxidizer and/or scrubber equipment.

3.4.4 Required Modifications to System Operation and Maintenance

Implementation of a catalytic oxidation system will eliminate handling of GAC vessels because they would no longer be used. Routine operation and maintenance procedures would include continued monitoring of influent and effluent vapor concentrations and flow rates, as well as new monitoring requirements such as the observation of catalytic oxidizer temperatures and caustic supply levels. Sampling and analysis of water being discharged from the scrubber system to the effluent tank would be performed to assure that pH is being properly controlled. The caustic supply tank would require replenishment with 25% sodium hydroxide solution once or twice per month, depending on the size of the tank. Maintenance activities would likely include an acid wash of the scrubber equipment once every 2 to 3 months.

Maintenance personnel should also use caution during any scrubber system maintenance, as the caustic spray in the scrubber can pose a safety hazard to the workers.

3.4.5 Wastes Generated

Operation of the catalytic oxidizer system would generate blowdown wastewater from the scrubber at a rate of 1 to 2 gal/hour. The blowdown water would contain approximately 25% sodium chloride (salt). However, it is expected that the blowdown could be discharged to the effluent tank and that the discharged groundwater would still have an acceptable salinity level for continued underground injection. There would be significant added cost if it would be necessary to store and transport the blowdown water for treatment.

Waste would also be generated from the acid wash of the scrubber every 2 to 3 months. One wash would generate less than one-half of a drum (55-gal) of waste, which would need to be neutralized onsite with caustic solution or treated as hazardous waste with appropriate offsite treatment and disposal.

3.4.6 Potential Releases to Air

The catalytic oxidation converts chlorinated VOCs into carbon dioxide and water (and chloride which is removed by the scrubber). Catalytic oxidizers for destruction of chlorinated hydrocarbons are typically designed to achieve a destruction efficiency of at least 98%. Operation of a similar system recently observed in Michigan achieves between 98% and 99% destruction efficiency of system vapors. However, based on prior experience with other catalytic oxidation systems, it is possible to achieve effluent VOC concentrations below laboratory detection limits. At 98% destruction efficiency, the system would emit less than 0.2 parts per million (ppm) of carbon tetrachloride into the atmosphere (based on a 9 ppm influent concentration). At that effluent concentration, and at the airflow rate from the 200-ZP-1 system, the carbon tetrachloride emission rate is calculated to be just above the acceptable source impact level of 0.067 $\mu g/m^3$ and would typically require air dispersion modeling to verify no anticipated unacceptable health risk. In order to stay within the current 10 lb/year discharge for carbon tetrachloride (which is the design basis of the current 200-ZP-1 system), destruction efficiency by the catalytic oxidation system would need to average greater than 99%, which may be difficult to achieve.

3.4.7 Life Expectancy of Technology

Because the catalyst bed of the oxidizer would be exposed to acid gases during operation, the catalyst may need to be replaced approximately every 3 to 5 years. However, information gathered from review of other catalytic oxidation systems being used for treatment of chlorinated vapors indicates that a longer operational lifespan is possible. One system operating at a paint manufacturing facility in Michigan for destruction of trichloroethylene has been operating since 2001 and the catalyst has not yet needed to be replaced in that 6-year period (*Catalytic Oxidation Site Visit Report: Paint Manufacturing Facility, 201 Woodword Height Blvd., Ferndale, Michigan* [FH 2007a]). Similar chlorinated catalytic oxidation systems have been operating for more than 10 years without needing to replace the catalyst.

3.4.8 Estimated Capital and Annual Operating Costs

Multiple vendors produce chlorinated VOC catalytic oxidizer and scrubber packages. Both Catalytic Combustion Corporation and Global Technologies, Inc. provided assistance with technical requirements and cost quotations. The capital cost of implementing catalytic oxidation at the 200-ZP-1 is estimated to be approximately $594,000, and the annual operating cost is estimated to be approximately $196,000. The present-value cost of this alternative for 10 years of system operation is estimated to be approximately $2,500,000. The details of this cost estimate are provided in Table 3-4.

Figure 3-1. Pump-and-Treat System with Larger Chiller/Condenser, 200-ZP-1 Site Plan.

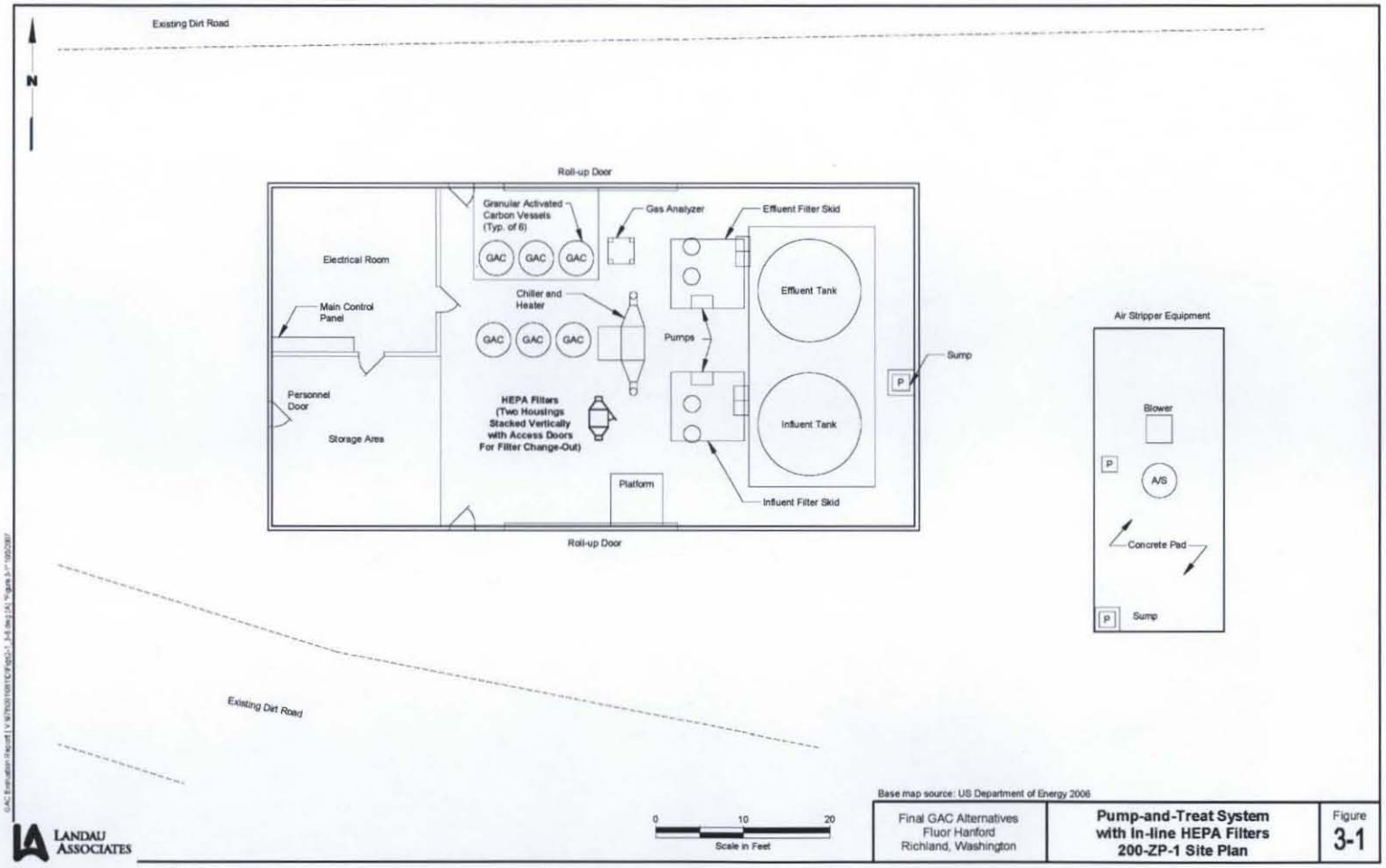

Figure 3-2. Pump-and-Treat System with Larger Chiller/Condenser, 200-ZP-1 Process Flow Diagram.

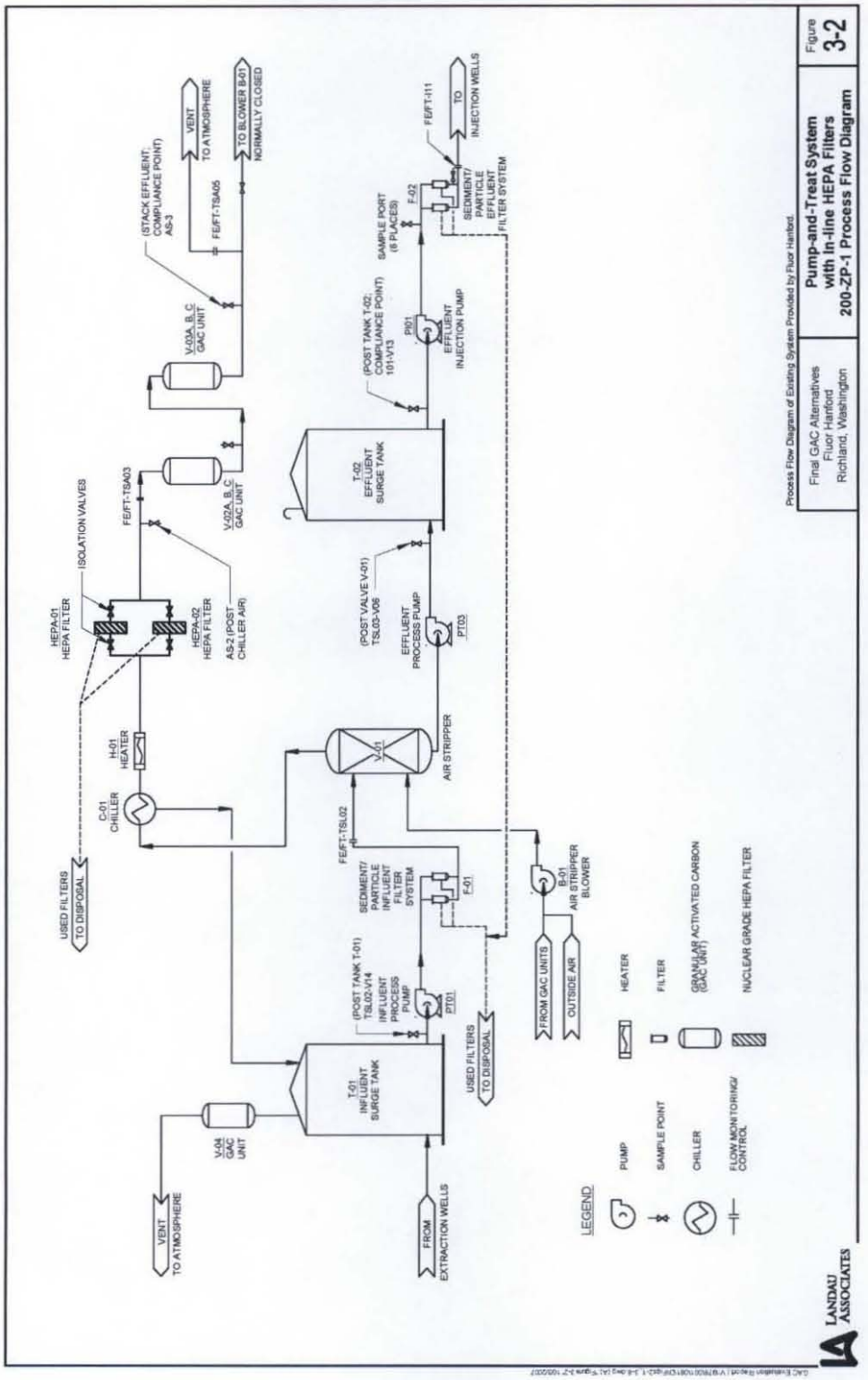

Figure 3-3. Pump-and-Treat System with High-Efficiency Particulate Air Filters, 200-ZP-1 Site Plan.

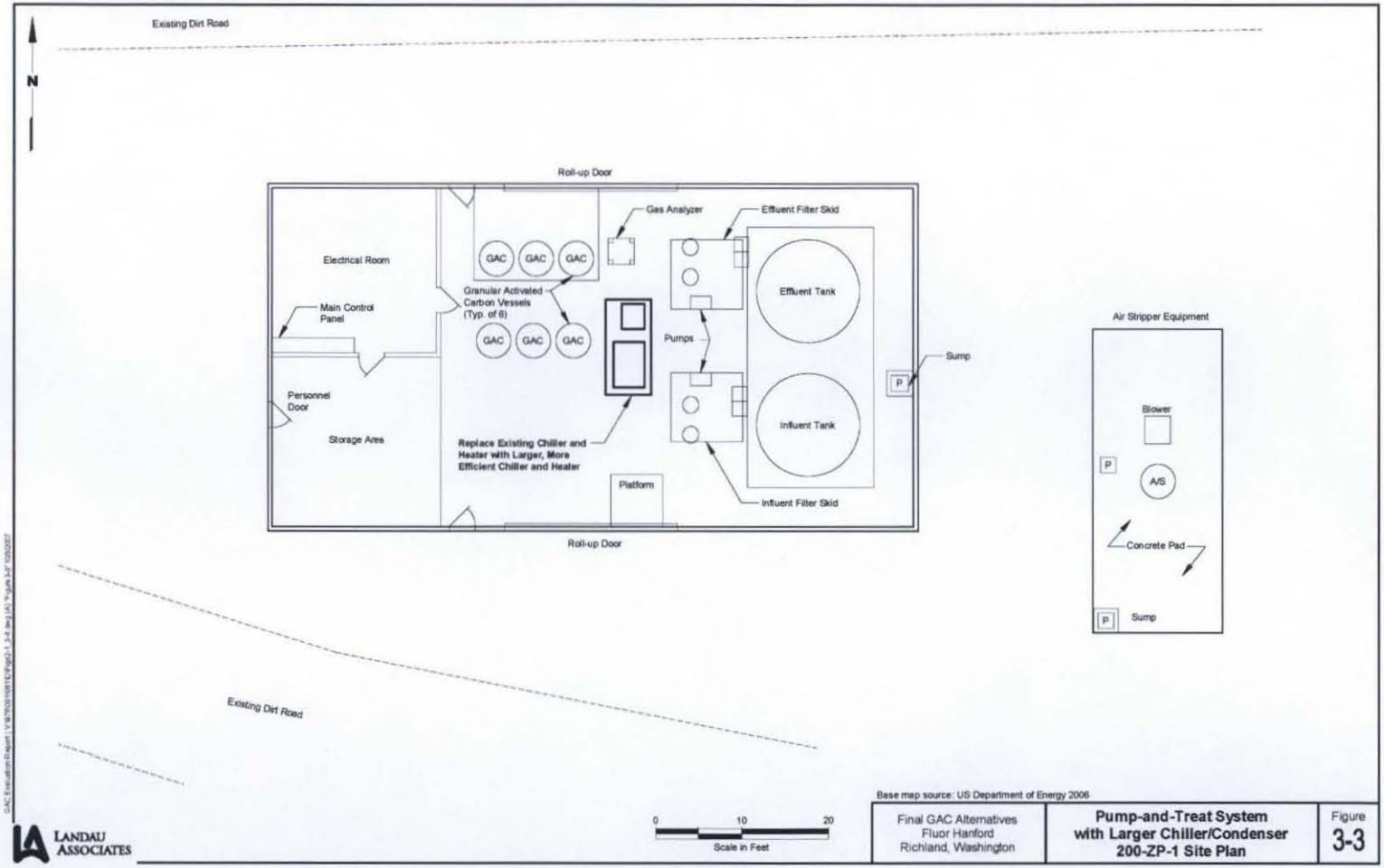

Figure 3-4. Pump-and-Treat system with High-Efficiency Particulate Air Filters, 200-ZP-1 Process Flow Diagram.

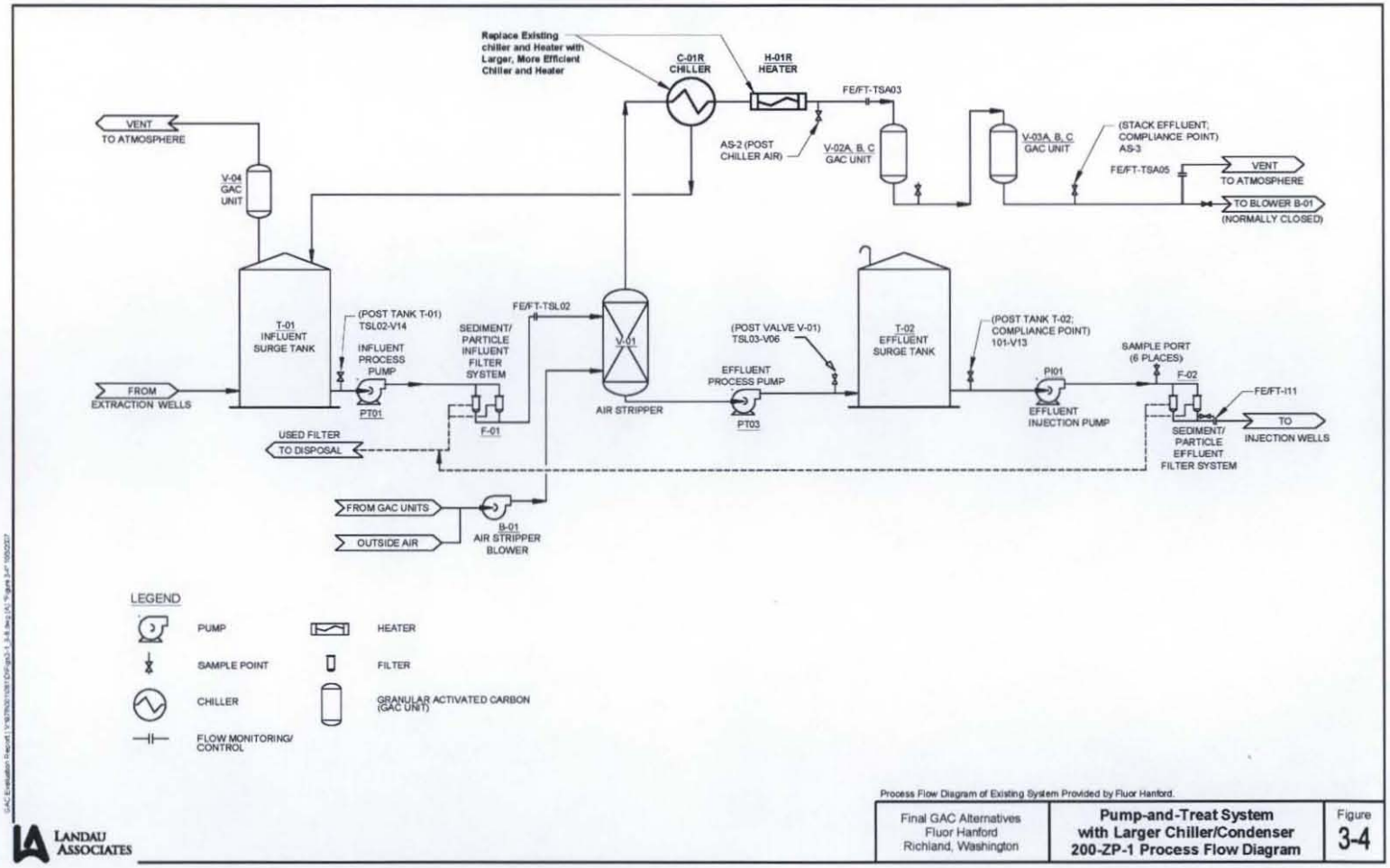

Figure 3-5. Pump-and-Treat System with Regenerative Carbon, 200-ZP-1 Site Plan.

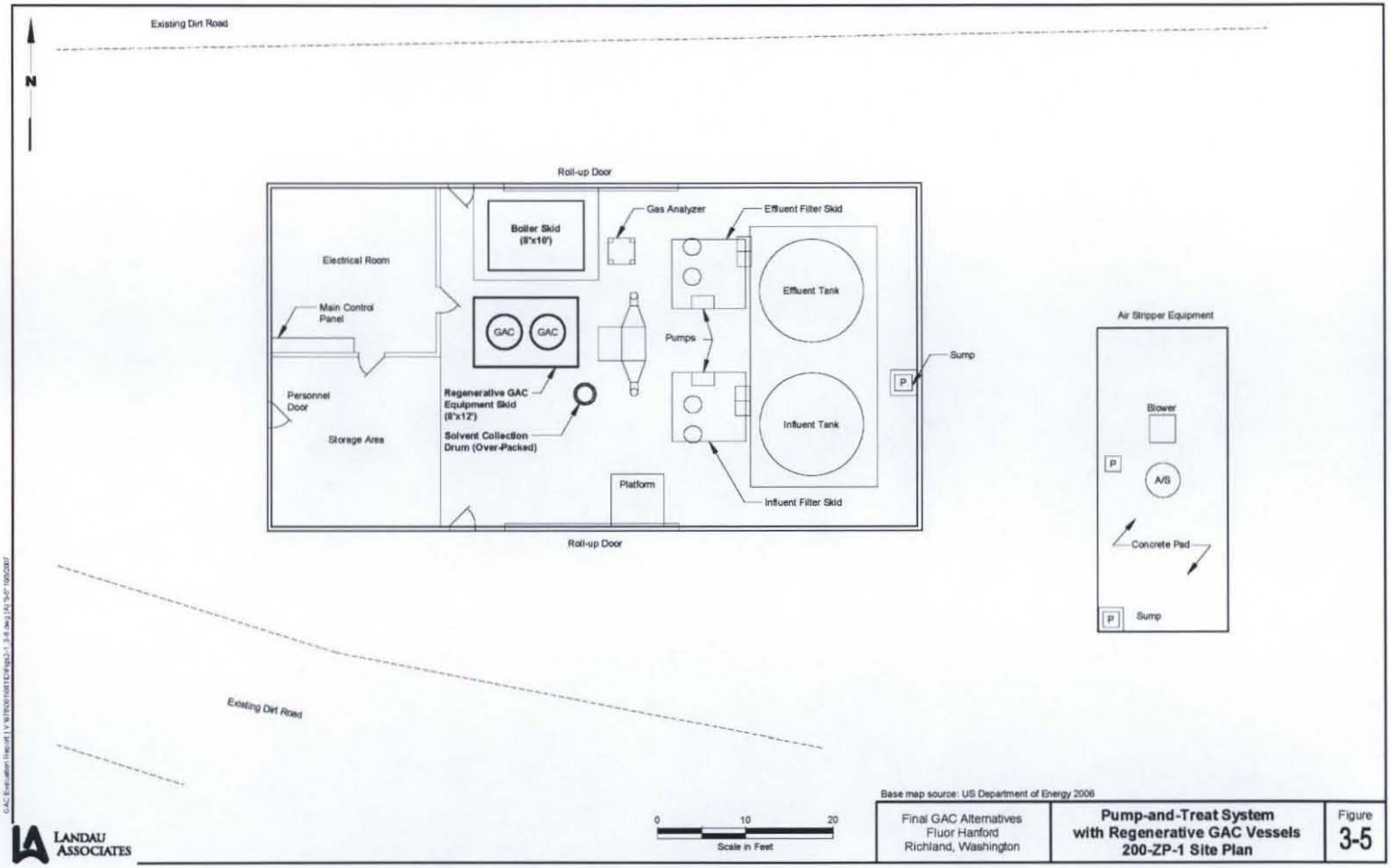

Figure 3-6. Pump-and-Treat System with Regenerative Carbon, 200-ZP-1 Process Flow Diagram.

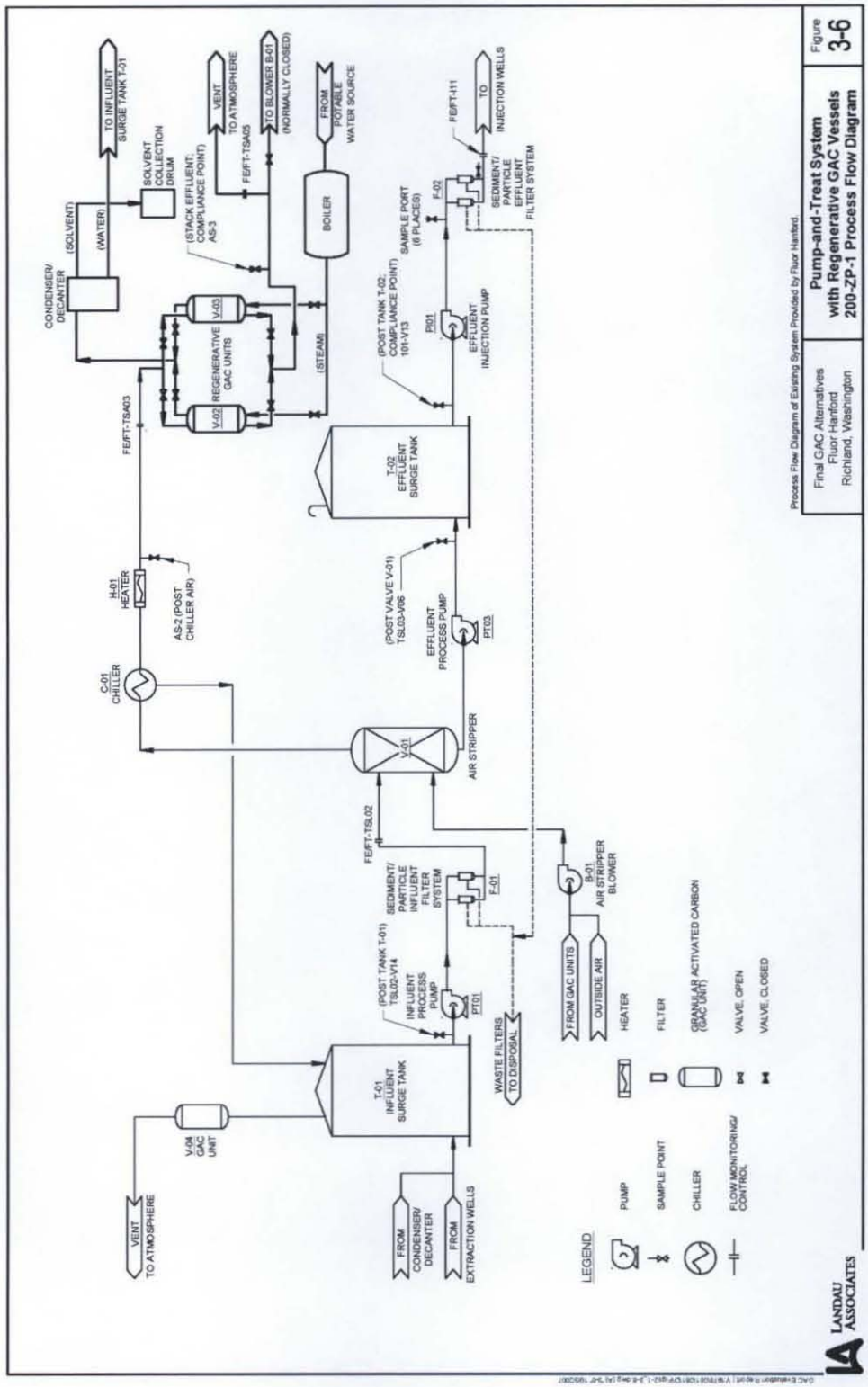

Figure 3-7. Pump-and-Treat System with Catalytic Oxidizer, 200-ZP-1 Site Plan.

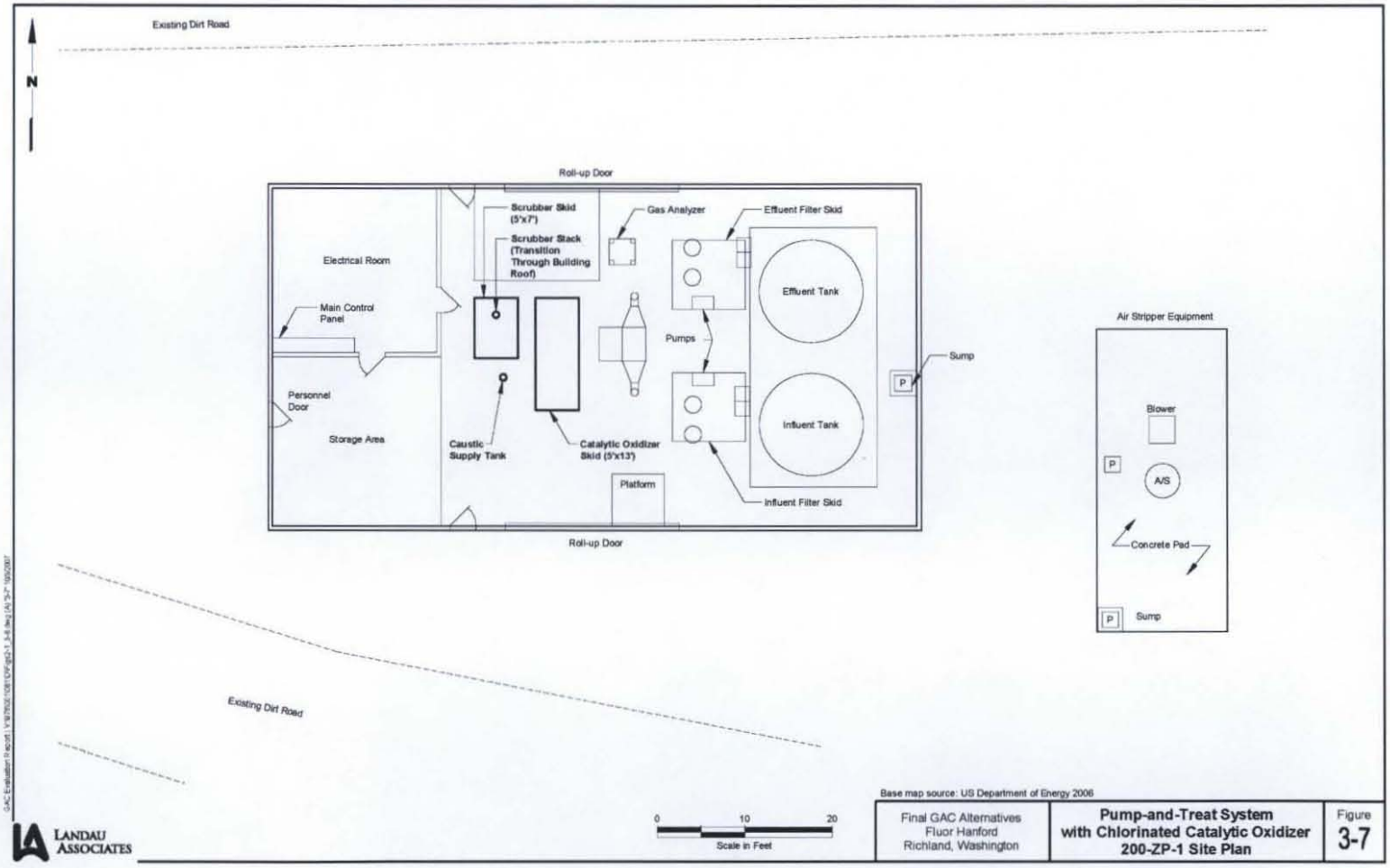

Figure 3-8. Pump-and-Treat System with Catalytic Oxidizer, 200-ZP-1 Process Flow Diagram.

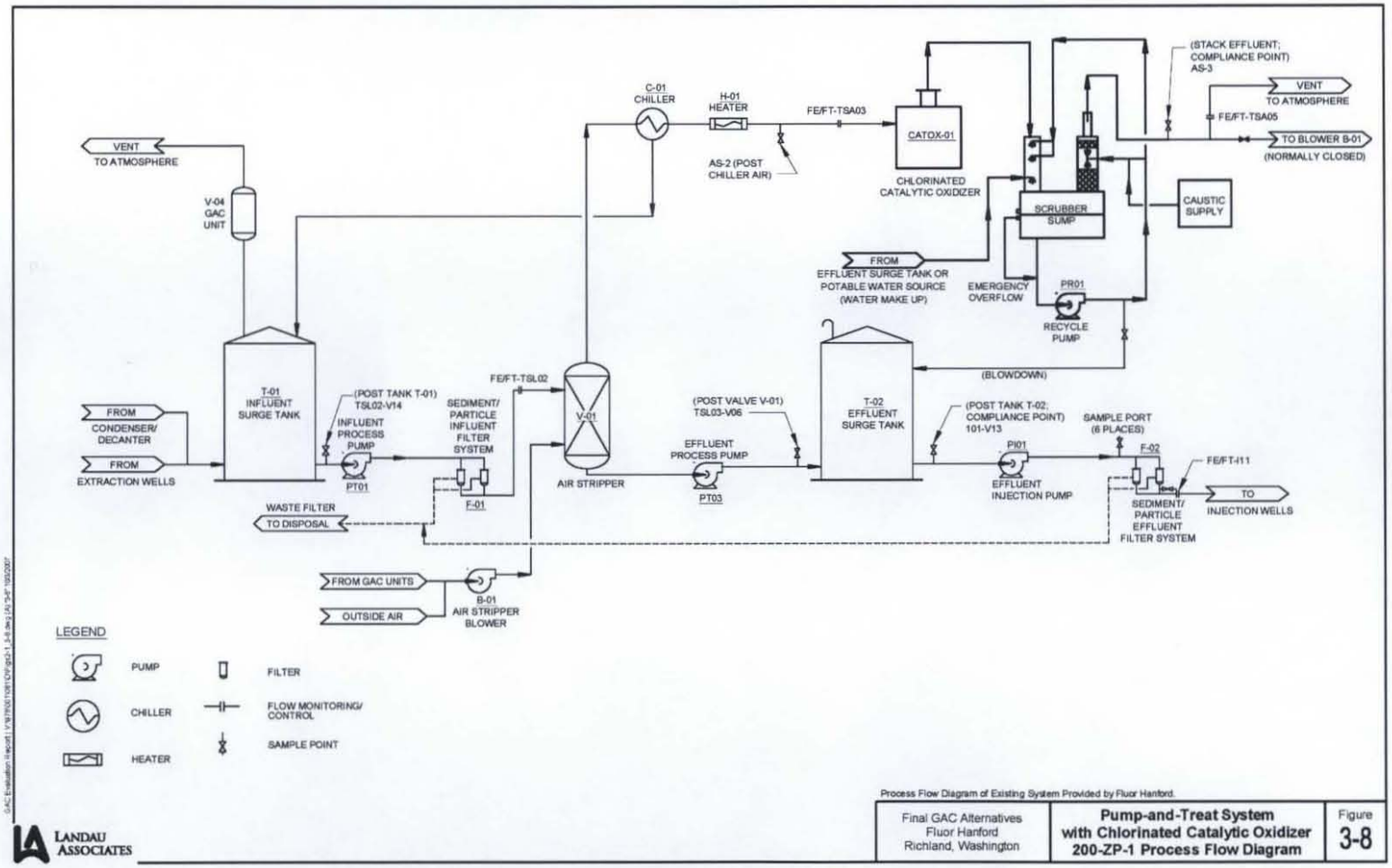

Table 3-1. Estimated Cost for High-Efficiency Particulate Air Filtration at 200-ZP-1. (2 sheets)

HEPA Filtration	Qty.	Unit	Unit Cost	Total	Comments
System Design and Capital Costs					
System design plans	1	LS	$10,000	$10,000	
HEPA filter housing	2	EA	$14,000	$28,000	To DOE specifications; including delivery.
Installation and ducting modifications	1	LS	$6,000	$6,000	
Differential pressure gauge	1	LS	$2,000	$2,000	Including installation.
Electrical and control system integration	1	LS	$0	$0	None required.
Update treatment system record drawings	2	EA	$3,000	$6,000	Update process and piping drawings.
Inspection and startup testing	1	LS	$10,000	$10,000	With influent and effluent samples.
Project management and coordination	10%			$6,000	
Total Estimated Capital Cost				**$68,000**	
Annual HEPA Filtration O&M Costs					
Operation and monitoring labor	52	hours	$70	$4,000	Estimated 1 extra hr/week.
Replacement HEPA filter elements	24	EA	$700	$17,000	Assume replace two filters/month.
Filter housing replacement	0	EA	$14,000	$0	Estimated 10-year housing life.
Effluent air sampling events, quarterly	4	EA	$3,000	$12,000	Air or GAC sample testing.
Annual equipment maintenance and repair	1	year	$3,000	$3,000	Estimated at 5% of capital cost.
Project management and coordination	10%			$4,000	
Estimated Annual O&M Cost				**$40,000**	

Table 3-1. Estimated Cost for High-Efficiency Particulate Air Filtration at 200-ZP-1. (2 sheets)

HEPA Filtration	Qty.	Unit	Unit Cost	Total	Comments
Present-Worth O&M (Years 1 to 10, Discount Rate = 4%)				**$324,000**	
Contingency	20%		$390,000	$65,000	
Total Estimated 10-Year Present-Value Cost				**$460,000**	Total rounded to nearest $10,000.

NOTES:
1. Costs, where totaled are rounded to the nearest $1,000 unless otherwise noted.
2. Estimated costs are for comparison purposes only. Costs shown do not include project costs that are common to all of the alternatives.

DOE = U.S. Department of Energy
GAC = granular activated carbon
HEPA = high-efficiency particulate air
O&M = operations and maintenance

Table 3-2. Estimated Cost for Larger Chiller/Condenser at 200-ZP-1. (2 sheets)

Improved Condenser System	Qty.	Unit	Unit Cost	Total	Comments
System Design and Capital Costs					
System design plans	1	LS	$10,000	$10,000	
New chiller/condenser system	1	EA	$50,000	$50,000	1,000 cfm capacity.
New heater unit	1	EA	$10,000	$10,000	
Installation and ducting modifications	1	LS	$15,000	$15,000	
Instrumentation	1	LS	$5,000	$5,000	Temperature gauges/transmitters.
Electrical and control system	1	LS	$30,000	$30,000	Including higher amp electrical panel.
Update treatment system record drawings	2	EA	$3,000	$6,000	Update process and piping drawings.
Inspection and startup testing	1	LS	$10,000	$10,000	With influent and effluent samples.
Project management and coordination	10%			$14,000	
Total Estimated Capital Cost				**$150,000**	
Annual Chiller/Condenser O&M					
Operation and monitoring labor	104	hours	$70	$7,000	Estimated 2 extra hrs/week.
Added electrical power for larger condenser/heater	12	months	$900	$11,000	Estimated extra 20 kW.
Chiller/condenser replacement	0	EA	$50,000	$0	Estimated 10-year lifetime.
Effluent air sampling events, quarterly	4	EA	$3,000	$12,000	Air or GAC sample testing.
Annual equipment maintenance and repair	1	year	$8,000	$8,000	Estimated at 5% of capital cost.
Project management and coordination	10%			$4,000	
Estimated Annual O&M Cost				**$42,000**	

Table 3-2. Estimated Cost for Larger Chiller/Condenser at 200-ZP-1. (2 sheets)

Improved Condenser System	Qty.	Unit	Unit Cost	Total	Comments
Present-Worth O&M (Years 1 to 10, Discount Rate = 4%)				**$341,000**	
Contingency	20%		$490,000	$68,000	
Total Estimated 10-Year Present-Value Cost				**$560,000**	Total rounded to nearest $10,000.

NOTES:
1. Costs, where totaled are rounded to the nearest $1,000 unless otherwise noted.
2. Estimated costs are for comparison purposes only. Costs shown do not include project costs that are common to all of the alternatives.

cfm = cubic feet per minute
GAC = granular activated carbon
O&M = operations and maintenance

Table 3-3. Estimated Cost for Onsite Steam Regeneration of Granular Activated Carbon at 200-ZP-1. (2 sheets)

Onsite Steam Regeneration of GAC	Qty.	Unit	Unit Cost	Total	Comments
System Design and Capital Costs					
System design plans	1	LS	$50,000	$50,000	
GAC steam regeneration system	1	LS	$500,000	$500,000	Quote from AMCEC, Inc., August 24, 2007.
Steam boiler	1	EA	$50,000	$50,000	Capacity of 120 lb/hr steam.
Boiler feed water pretreatment system	1	LS	$100,000	$100,000	Using treated groundwater.
Installation; piping and ducting modifications	1	LS	$40,000	$40,000	
Expanded electrical power feed to building	1	LS	$100,000	$100,000	New feed cable and transformer.
Electrical and control system	1	LS	$60,000	$60,000	Includes 480V, 700-amp electrical panel.
Installation completion report and record drawings	1	LS	$20,000	$20,000	
Inspection and startup testing	1	LS	$20,000	$20,000	
Project management and coordination	10%			$94,000	
Total Estimated Capital Cost				**$1,034,000**	
Annual Onsite GAC Regeneration O&M					
Operation and monitoring labor	200	hours	$70	$14,000	Estimated extra 4 hrs/week.
Equipment replacement	0	LS	$550,000	$0	Estimated 10-year lifetime.
Electrical power, 547 kW, 10% duty cycle	12	months	$2,400	$29,000	Assuming $0.06/kW-hr.
System sampling/analysis	0	EA	$0	$0	Assuming no extra sampling required.
Offsite incineration of recovered VOCs	3	drum	$5,000	$15,000	Including coordination labor.
Annual equipment maintenance and repair	1	year	$52,000	$52,000	Estimated at 5% of capital cost.
Project management and coordination	10%			$11,000	
Estimated Annual O&M Cost				**$78,000**	

Table 3-3. Estimated Cost for Onsite Steam Regeneration of Granular Activated Carbon at 200-ZP-1. (2 sheets)

Onsite Steam Regeneration of GAC	Qty.	Unit	Unit Cost	Total	Comments
Present-Worth O&M (Years 1 to 10, Discount Rate = 4%)				**$633,000**	
Contingency	20%		$1,670,000	$127,000	
Total Estimated 10-Year Present-Value Cost				**$1,800,000**	Total rounded to nearest $100,000.

NOTES:
1. Costs, where totaled are rounded to the nearest $1,000 unless otherwise noted.
2. Estimated costs are for comparison purposes only. Costs shown do not include project costs that are common to all of the alternatives.

GAC = granular activated carbon
O&M = operations and maintenance
VOC = volatile organic carbon

Table 3-4. Estimated Cost for Catalytic Oxidization at 200-ZP-1. (2 sheets)

Catalytic Oxidation	Qty.	Unit	Unit Cost	Total	Comments
System Design and Capital Costs					
System design plans	1	LS	$50,000	$50,000	
Catalytic oxidizer system	1	LS	$370,000	$370,000	Catalytic Combustion quote, September 4, 2007.
Installation; piping and ducting modifications	1	LS	$40,000	$40,000	
Expanded electrical power feed to building	1	LS	$75,000	$75,000	New feed cable and transformer.
Electrical and control system	1	LS	$40,000	$40,000	Includes 480V, 330-amp electrical panel.
Installation completion report and record drawings	1	LS	$20,000	$20,000	
Inspection and startup testing	1	LS	$20,000	$20,000	
Project management and coordination	10%			$62,000	
Total Estimated Capital Cost				**$677,000**	
Annual Catox System O&M					
Operation and monitoring labor	200	hours	$70	$14,000	Estimated extra 4 hrs/week.
Equipment replacement	0	LS	$370,000	$0	Estimated 10-year lifetime.
Electrical power, 260 kW for catox and scrubber	12	months	$11,200	$134,000	Assuming $0.06/kW-hr.
System sampling/analysis	0	EA	$0	$0	Assuming no extra sampling required.
Equipment repair including new catalyst every 3 years	1	year	$34,000	$34,000	Estimated at 5% of capital cost.
Project management and coordination	10%			$18,000	
Estimated Annual O&M Cost				**$200,000**	

Table 3-4. Estimated Cost for Catalytic Oxidization at 200-ZP-1. (2 sheets)

Catalytic Oxidation	Qty.	Unit	Unit Cost	Total	Comments
Present-Worth O&M (Years 1 to 10, Discount Rate = 4%)				**$1,620,000**	
Contingency	20%		$2,300,000	**$320,000**	
Total Estimated 10-Year Present-Value Cost				$2,600,000	Total rounded to nearest $100,000.

NOTES:
1. Costs, where totaled are rounded to the nearest $1,000 unless otherwise noted.
2. Estimated costs are for comparison purposes only. Costs shown do not include project costs that are common to all of the alternatives.

O&M = operations and maintenance

4.0 CONCLUSIONS AND RECOMMENDATIONS

Given that FH has received authorization from NRC to resume the offsite shipment and regeneration of GAC from the 200-ZP-1 and 200-PW-1 OUs and given that the four alternative technologies evaluated here would require significant additional cost and are uncertain as to their full effectiveness, proceeding with implementation of any of these alternatives would not be recommended at this time.

However, if there were to be again a halt on offsite regeneration of GAC due to low-level radioactivity, then it would be worth testing the lowest-cost alternative that was identified in this evaluation. The lowest-cost alternative was estimated to be HEPA filtration of the vapor stream prior to contact with the GAC.

Alternatively, in the event that detected low-level radioactivity has made offsite GAC regeneration no longer permissible, and HEPA filtration by itself has been found to be ineffective in adequately reducing the level of radioactivity on the GAC, then increasing the size of the chiller/condenser would be the next least-expensive alternative to test.

If these two alternatives together were still found to be ineffective in removing radioactivity to the level necessary, or if it was otherwise determined that offsite regeneration of GAC could not continue, then onsite steam regeneration of GAC would be the preferred technology for implementation due to its significantly lower operational cost compared to catalytic oxidation. However, remaining concerns that would need to be further examined prior to implementing onsite steam regeneration of GAC include (1) confirming that a small split stream of treated groundwater could be used for boiler feed water, (2) confirming the cost for bringing in a significantly larger electrical power supply to run the boiler, and (3)confirming that the recovered liquid carbon tetrachloride waste stream would not contain levels of radioactivity that would prevent it from being sent offsite for incineration.

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