Construction of the Largest Radionuclide Commingled Plume Groundwater Treatment Facility for the Department of Energy at the Hanford Site – 12411

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ABSTRACT

CH2M HILL Plateau Remediation Company (CHPRC) has constructed the largest groundwater treatment systems of its kind throughout the DOE Complex at the Hanford Site in an accelerated manner with American Recovery and Reinvestment Act (ARRA) funds. This complex, one of a kind groundwater treatment facility in Washington State has also attained Leadership in Energy and Environmental Design (LEED) GOLD certification.

The original concept for the 200 West Area groundwater treatment facility was a 6100 liter per minute (1,600 gallon per minute) facility. With additional ARRA funding, the plant design was improved to construct a 9500 liter per minute (2,500 gallon per minute) facility with expansion areas up to 14,000 liter per minute (3,750 gallon per minute). The current design will remove 53 percent more mass per year for faster clean-up. It is also expected to treat extracted groundwater to 25 percent or less than the Record of Decision-specified limit which improves Monitored Natural Attenuation (MNA) effectiveness.

BACKGROUND

The United States Department of Energy (DOE) Hanford Site is a 1517.74 square kilometer (586 square mile) Federal facility located in southeastern Washington State along the Columbia River. The operations at Hanford created one of the largest and most complex cleanup projects in the United States. Weapons production resulted in more than 32 million cubic meters (43 million cubic yards) of radioactive waste and over 99 million cubic meters (130 million cubic yards) of contaminated soil and debris. Approximately 180 billion kiloliters (475 billion gallons) of contaminated water was discharged to the soil. Some of the contaminants have made it to groundwater under the site. Over 207 square kilometers (80 square miles) of groundwater is contaminated to levels above groundwater protection standards.

Beginning in 1989, the primary mission at the Hanford Site switched from production to waste cleanup. In May of that year, the DOE, the U.S. Environmental Protection Agency (EPA), and Washington State Department of Ecology (Ecology), referred to as the “Tri-Parties,” signed the Tri-Party Agreement (TPA). The TPA outlines cleanup milestones to guide cleanup activities and provide deadlines.

For administrative purposes, the Hanford Site was divided into four National Priorities List (NPL) (40 Code of Federal Regulations [CFR] 300, Appendix B) sites in 1989 under the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), and one of these sites is the 200 Areas. The 200 Area NPL site, or Hanford’s Central Plateau, encompasses approximately 190 square kilometers (75 square miles) near the center of the

Hanford Site and contains multiple waste sites, contaminated facilities, and groundwater contamination plumes.

Historical Work Conducted

To facilitate cleanup, these waste sites, facilities, and groundwater plumes have been grouped by geographic areas, process types, or cleanup components into several operable units (OUs).

The 200-ZP-1 OU is one of four groundwater OUs located on the Central Plateau. Each groundwater OU has its own plan of study, enforceable schedule, and Record of Decision (ROD). On September 29, 2008, the Record of Decision, Hanford 200 Area, 200-ZP-1 Superfund Site, Benton County, Washington (EPA et al. 2008) [1] (hereinafter referred to as the ROD) was approved by the Tri-Parties.

The major waste streams that contributed to groundwater contamination in the 200-ZP-1 OU were associated with plutonium-separation operations at the T Plant facilities and plutonium concentration and recovery operations at the Z Plant facilities in the Central Plateau. The liquid waste disposal in the cribs and trenches near these facilities resulted in several groundwater contamination plumes in the 200-ZP-1 OU. The major constituents of concern (COC) for the 200-ZP-1 OU are carbon tetrachloride and Tc-99. The other COCs are total chromium (trivalent [III] and hexavalent [VI]), nitrate, trichloroethylene (TCE), iodine-129, and tritium.

The DOE has operated an interim remedial measure (IRM) pump-and-treat system to prevent carbon tetrachloride from spreading in the 200-ZP-1 OU since 1994. Carbon tetrachloride concentrations have decreased in the original target area (Figure 1). Since 1994, more than 3.7 billion liters (975 million gallons) of groundwater have been extracted and more than 10,900 kilograms (24,000 pounds) of carbon tetrachloride have been removed from groundwater and treated since 1994.

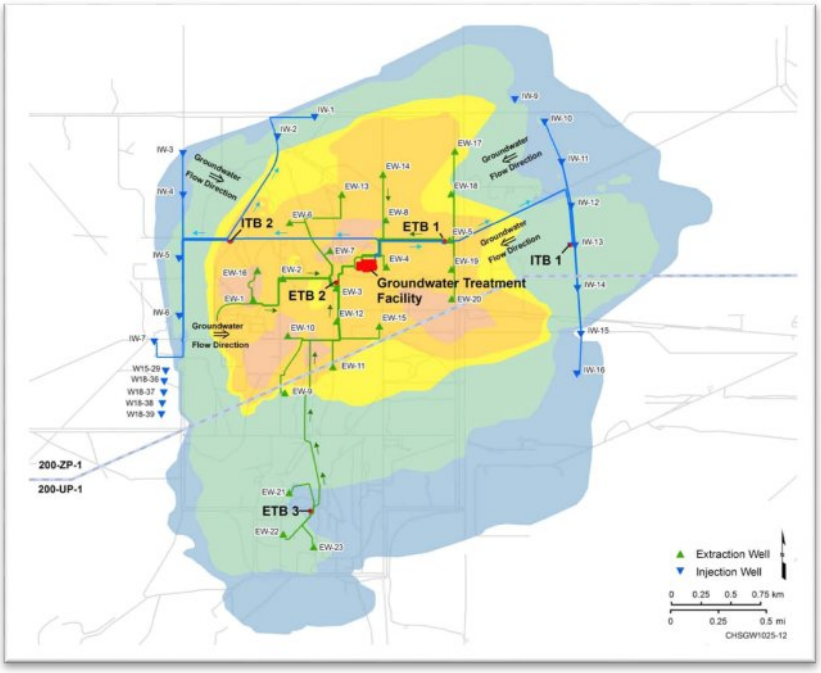

Figure 1. 200 West Well Network and Flow Logic

Current Project Construction and Remediation Strategy

The selected remedy for the 200-ZP-1 OU in accordance with Part 2, Section 12.2 of the ROD is, “Pump-and-Treat, Monitored Natural Attenuation (MNA), Flow-Path Control, and Institutional Controls”.

By the time of the conference, the project will be in the middle of an integrated acceptance test to address all design issues prior to going to operational testing (contaminated groundwater).

The 4800-square-meter (52,000-square-foot) facility is the largest facility of its kind ever constructed on any DOE site. The system has the capacity to nominally treat 9500 liter per minute (2,500 gallon per minute). Over the course of its operational life, the “unique” treatment system is designed to extract and treat both chemical and radioactive constituents simultaneously, at a rate of up to 49,500 kilograms (110,000 pounds) of carbon tetrachloride, treating more than 91 million kiloliters (24 billion gallons) of groundwater in the process.

REMEDIAL DESIGN

ROD Design COCs and Processes

Following extraction, the COCs in groundwater (except tritium) will be treated to achieve, at a minimum, the final cleanup levels listed in the ROD Table 11, and then the groundwater will be reintroduced to the aquifer through injection wells placed to provide flow path control.

For two of the primary COCs requiring active treatment to meet the cleanup levels (carbon tetrachloride, and technetium-99[Tc-99]), the above-ground treatment system is being constructed to achieve a nominal operating treated effluent target of 60 percent of the final cleanup level under normal operations (thus, 2 microgram per liter for carbon tetrachloride and 540 picocuries per liter for Tc-99). These process design levels will provide an allowance for a slight upward trend during stressed operating periods. The upward trend will be acted on by the operations staff to bring the system back to normal operations. Nitrate, which also must be treated to meet the cleanup levels will be designed to achieve a nominal operating treated effluent target of 20 percent of the cleanup level (thus 2,000 microgram per liter as nitrogen). This lower level is being selected because biological treatment systems are not very stable and an extra operating margin is desired. The system will not be specifically designed to treat 60 percent of the final cleanup levels for the other COCs (chromium (hexavalent and total), TCE, and I-129) because the blended influent will either be below or close to the cleanup levels, or they will be removed concurrently with the primary COCs. For example, TCE will be removed with the carbon tetrachloride and hexavalent chromium will be removed with the nitrate.

Table I. Process Design Summary

Unit Process	Process Benefit	Targeted Finished Water Quality Parameter *
Ion Exchange	Removal of Tc-99 and uranium and possibly Iodine-129	Tc-99
Anoxic/Anaerobic Biodegradation	Removal of nitrate and possibly degradation of carbon tetrachloride Conversion of hexavalent chromium to trivalent state	Nitrate Carbon Tetrachloride Hexavalent Chromium
Aerobic Biodegradation	Degradation of residual organic carbon	Basis of Design (BOD) to meet aquifer

Unit Process	Process Benefit	Targeted Finished Water Quality Parameter *
	substrate	injection requirements
Membrane Filtration	Removal of particles, biomass and precipitated trivalent chromium	Total Chromium Turbidity and BOD Removal to meet aquifer injection requirements
Air Stripping	Removal of volatile organic compounds including carbon tetrachloride and trichloroethylene	Carbon Tetrachloride Trichloroethylene
Gravity Thickening	Reduce solids quantity for disposal	Not Applicable
Sludge Dewatering	Reduce solids quantity for disposal	Not Applicable
Finished Water Chemistry Adjustment	Provide finished water stability	pH and Alkalinity to meet aquifer injection requirements

* No removal required for tritium or Iodine-129.

GENERAL CONSTRUCTION

The construction of the facility includes six process buildings: two Extraction Transfer Buildings (ETBs), two Injection Transfer Buildings (ITBs), and the Radiological and Biological Buildings (Main Facility)(Figure 2).

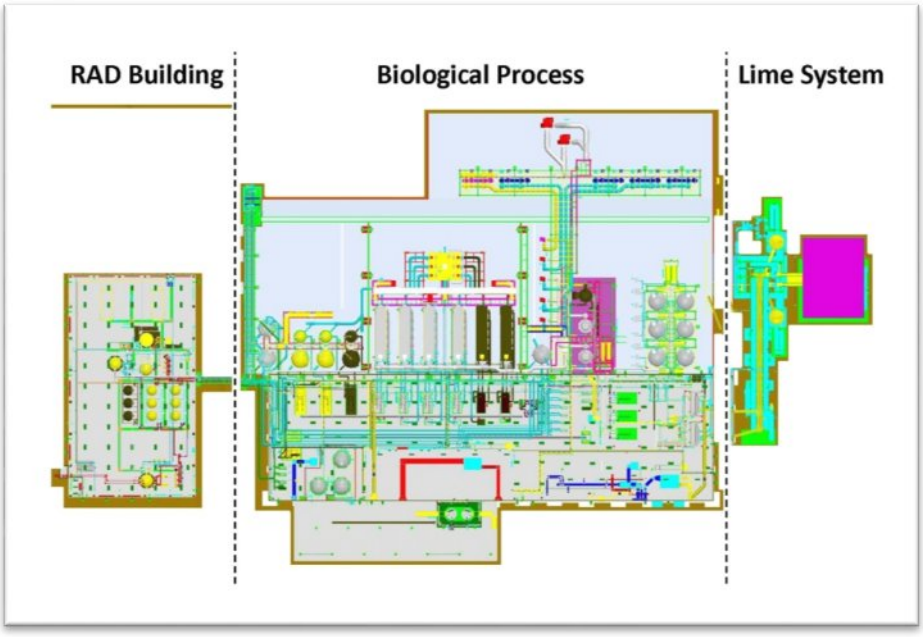

Figure 2. Plan View of Radiological (RAD) Building, Biological Building and Sludge Stabilization System

BALANCE OF PLANT DELIVERY SYSTEM CONSTRUCTION

The output from extraction wells will be pumped via above ground high-density polyethylene (HDPE) pipeline to an ETB for consolidation and pumping to the Main Facility, or pumped

directly to the Main Facility. There have been 70 road crossing and 51.2 kilometers (32 miles) of HDPE pipe installed.

ETB #1 measures 7.3 meters (24 feet) by 15 meters (50 feet) and contains one extraction tank. It is located in an area of no radioactive contaminates with delivery directly to the Biological Building;

ETB #2measures 14.6 meters (48 feet) by 15 meters (50 feet) and contains two extraction tanks. One tank feeds the Radiological Building and one feeds the Biological Building; the goal being to minimize the total cost of pipe and pumping equipment needed to transfer the groundwater to the Main Facility.

The output from the Main Facility will be pumped to two 14.6X15 meter (48x50 foot) ITBs; the goal being to minimize the total cost of pipe and pumping equipment needed to transfer the groundwater from the Main Facility to the injection wells.

The numerical modeling conducted showed that no wells had an average concentration above the final cleanup level of 1.0 picocuries per liter. Concentration into the treatment train is estimated to be 0.31 picocuries per liter at startup.

PROCESS CONSTRUCTION

Radiological Building

Radionuclide Ion Exchange System

Groundwater from extraction wells that feed ETB #2 will contain concentrations of Tc-99 greater than 900 picocuries per liter. It will be pretreated separately in the Radiological Building with ion exchange resins to reduce the concentrations of radionuclides. Incoming groundwater will be sent through cartridge filters to remove fine particulate matter. Filtered water flows to ion exchange vessels (up to three in series) containing a resin which has demonstrated reliable and predictable reduction of Tc-99. The ion exchange effluent will flow through bag filters which serve as a resin trap, then it will be directed to the Biological Building for further treatment. When the ion exchange resin reaches its loading limit, it will be removed from the vessel by sluicing it with treated water from the Biological system (finished water) into a carbon tetrachloride stripping tank (Strip Tank). In the Strip Tank, the resin will be fully submerged in finished water and heated up to 93 degrees Celsius (200 degrees Fahrenheit). Air will be bubbled through the resin bed (about 1416 standard liters per minute [50 standard cubic feet per minute]) to mix the bed and strip off carbon tetrachloride. The vapor emission will be treated with Vapor Phase Granular Activated Carbon (VPGAC). The VPGAC will be void of residual radionuclide and therefore will be regenerated offsite and returned to plant. After treatment (6 to 24 hours), the stripping water will be pumped to the Biological Building for treatment. The resin will be sluiced with finished water and placed in a container to allow drainage. The drainage will be collected and pumped to the bag filters at the end of the Tc-99 IX System. The dewatered resin will be transported to the landfill for disposal.

Water from the Radiological Building will flow to the Biological Building equalization tank where it will be blended with the extracted groundwater from tank #2 in ETB #2 and the tank in ETB #1. The treatment process for carbon tetrachloride and nitrate removal will have one treatment train initially to accommodate flow ranges up to 4730 liters per minute (1,250 gallons per minute).

Biological Building

Fluidized bed reactor (FBR)

The water from the recycle tank will be pumped to the fluidized bed reactor (FBR). The feed water directed to the FBR process should be maintained above 10 degrees Celsius (50 degrees Fahrenheit). The FBR is for nitrate and potentially for carbon tetrachloride removal. The FBR will be operated under an anoxic condition (no dissolved oxygen) to reduce the nitrate-nitrogen to nitrogen gas by the heterotrophic facultative bacteria. Nitrate-nitrogen acts as an electron acceptor in the absence of dissolved oxygen. Organic carbon is an electron donor and energy source for bacteria.

The FBR vessel contains an integral fluidization and effluent collection system designed to enhance uniform flow distribution for anoxic and anaerobic microbial growth. The water is pumped into the bottom of the FBR creating up flow to suspend the granular activated carbon (GAC) media. The FBR will initially be seeded with microbes that are suited for nitrate-nitrogen removal (denitrification) and possibly carbon tetrachloride degradation. An organic carbon substrate called MicroCg® and phosphorus will be added into the FBR to serve as the electron donor and nutrient to promote microbial growth. As the microbes grow on the GAC, the fluidized bed height will expand. Some excess biomass will be removed by the normal flow through the FBR. Additional excess biomass will be removed with a biomass separator and will flow out with the effluent. The effluent from the FBR will flow by gravity to covered membrane tanks for removal of the residual carbon substrate through aerobic biodegradation and removal of the total suspended solids (TSS) including biomass from the FBR.

Membrane bed reactor (MBR)

The membrane tanks will have aeration capacity which will provide sufficient oxygen for maintenance of the aerobic biological process in order to reduce the residual carbon substrate. The membrane tanks will have an aeration zone followed by a zone with submerged membranes for filtration. The aeration zone will have a blower that diffuses air into the tank that continues the aerobic biodegradation of carbon substrate. There will also be a blower in the membrane zone for air scouring to remove accumulated organic debris from the membrane surface and maintain permeability.

In the membrane zone, there will be modules of vertically or horizontally strung membrane fibers. Water will be filtered by applying a slight vacuum to the end of each fiber which draws the water through the tiny pores into the fibers. These filters will remove solids to less than 0.1 nephelometric turbidity unit (NTU) with the biosolids and particles remaining in the tank concentrate. A portion of the concentrate will be recycled to the first compartment of the membrane tank to maintain the biomass concentration (i.e., mixed liquor volatile suspended solids [MLVSS]) needed to reduce the BOD. To prevent fouling of the membranes, maintenance cleanings will be required. This will involve draining a section of the membrane tank, refilling it with a cleaning solution, and soaking the membrane modules for several hours. The solution is then drained and chemical residues are flushed with treated wastewater before returning the tank to service.

Air Stripper

The treated water from the membranes will be pumped to a packed-bed tower air stripper for removal of the remaining carbon tetrachloride and other volatile organic compounds. Off-gas from the stripper, influent equalization tank, FBR(s), membrane tanks, sludge holding tank(s), rotary drum thickeners, and centrifuges will be combined and treated by VPGAC; the off-gas is estimated to be 172,700 standard liters per minute (6,100 standard cubic feet per minute) for

the 4730 gallons per minute (1,250 gallons per minute) flow (refer to 382519-CALC-022). To avoid unwanted build-up of radionuclides in the VPGAC, all air streams to the VPGAC system must be pretreated by a demister to minimize any liquid water mist carryover. The air stripper-treated effluent will be pumped to the Biological Building effluent tank. The pH of the air stripper effluent will be lowered slightly using sulfuric acid mixed through an inline static mixer.

Solid Waste

Solids from the membrane tanks will be pumped to the rotary drum thickeners for sludge thickening. A bypass line to the sludge holding tanks will be provided with an automatic control valve to bypass a portion of the flow around the rotary drum thickeners to maintain a solids level in the tank between 2.0 percent and 2.5 percent solids. As the solids concentration in the aerated sludge holding tank decreases, less flow will be bypassed around the thickeners; conversely, as the solids concentration in the tank increases, more flow will be bypassed around the thickening process. Polymer will be added upstream of the rotary drum thickeners, if necessary, to thicken the solids. The sludge holding tanks will be aerated for aerobic digestion of the solids and to keep the solids from becoming anaerobic. The thickened solids will be pumped from the sludge holding tank to centrifuges for dewatering on a periodic basis. Polymer will be added upstream of the centrifuges to aid in solids dewatering. A screw conveyor will be used to move the dewatered sludge from the centrifuge to a sludge stabilization system (lime addition) prior to placement in containers for disposal at the landfill. The supernatant from the rotary drum thickeners and centrifuges will be sent to the centrate collection tank and then pumped to the recycle tank located upstream of the FBR. Wet solids that result from startup and shutdown of the centrifuge dewatering equipment will be returned to the sludge holding tank.

BENEFITS

Funding from the American Recovery and Reinvestment Act (ARRA) created a funding mechanism to expedite the construction of the plant. The project touched not only the immediate area of the Hanford Site but throughout the country.

The majority of the process of equipment was procured in parallel with the design of the facility. The manufacturing of the process equipment was completed utilizing six vendors. Factory acceptance tests were completed in 4 states in two countries. The design was completed utilizing 51 CH2M HILL corporate offices that contributed 351 staff members over a 20 month period. Construction was completed over a 15 month timeline with a sustained peak of about 350 craft personnel.

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References

1. EPA, Ecology, and DOE. (2008, October 20). *Record of Decision Hanford 200 Area 200 ZP 1 Superfund Site Benton County, Washington (transmitted via letter 09 AMCP 0003)*. Olympia, Washington: U.S. Environmental Protection Agency, Washington State Department of Ecology, and U.S. Department of Energy. Available at: http://www5.hanford.gov/arpir/?content=findpage&AKey=0810240402.